MAP I–1932

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF PALEOZOIC AND MESOZOIC ROCKS IN PARTS OF THE DARWIN AND ADJACENT QUADRANGLES, INYO COUNTY, CALIFORNIA

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and Rachel M. Gulliver

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STONE AND OTHERS–GEOLOGIC MAP, DARWIN AND ADJACENT QUADS, CALIFORNIA—1:31,250 MAP I–1932

DEPARTMENT OF THE INTERIOR
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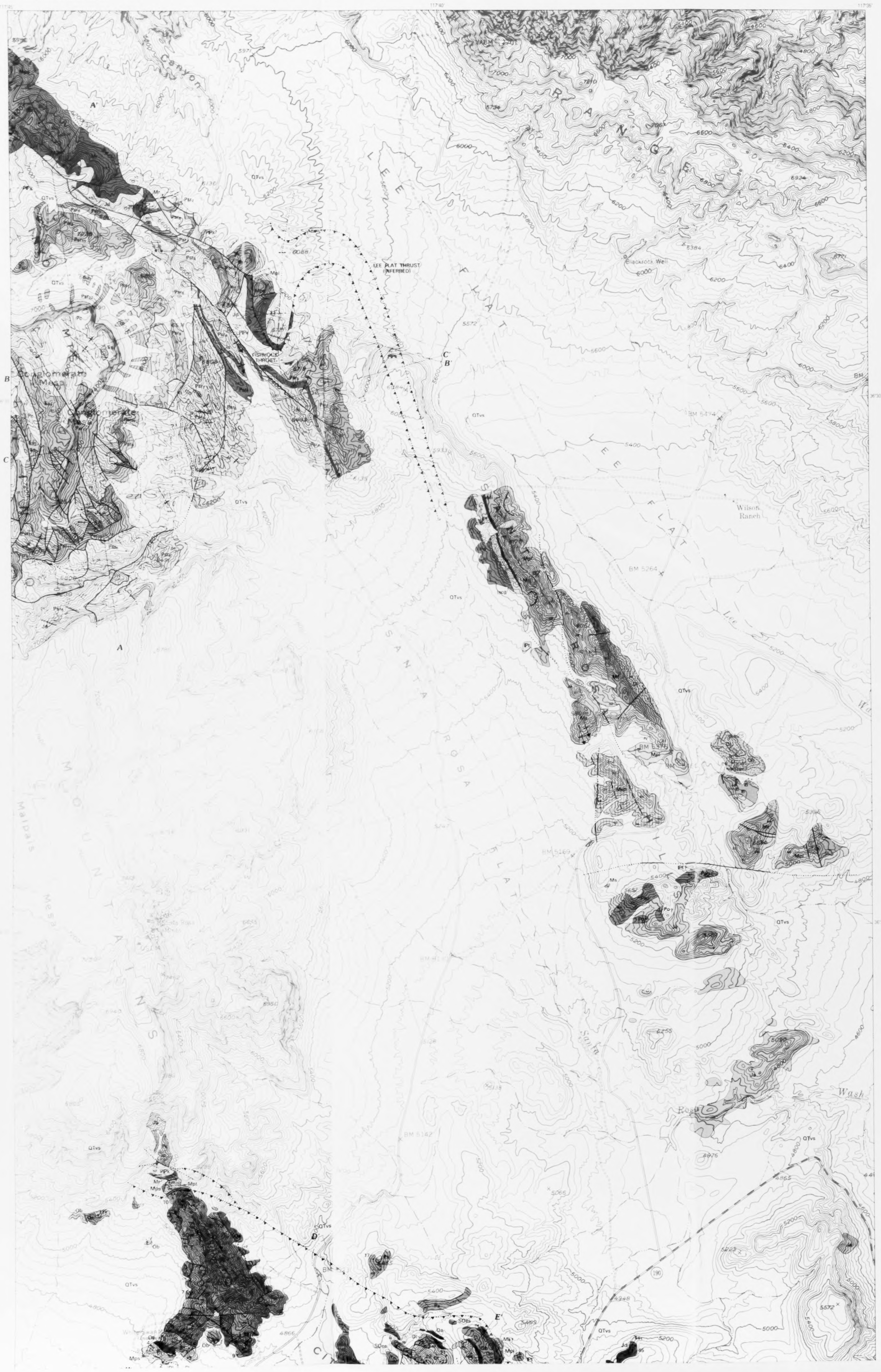
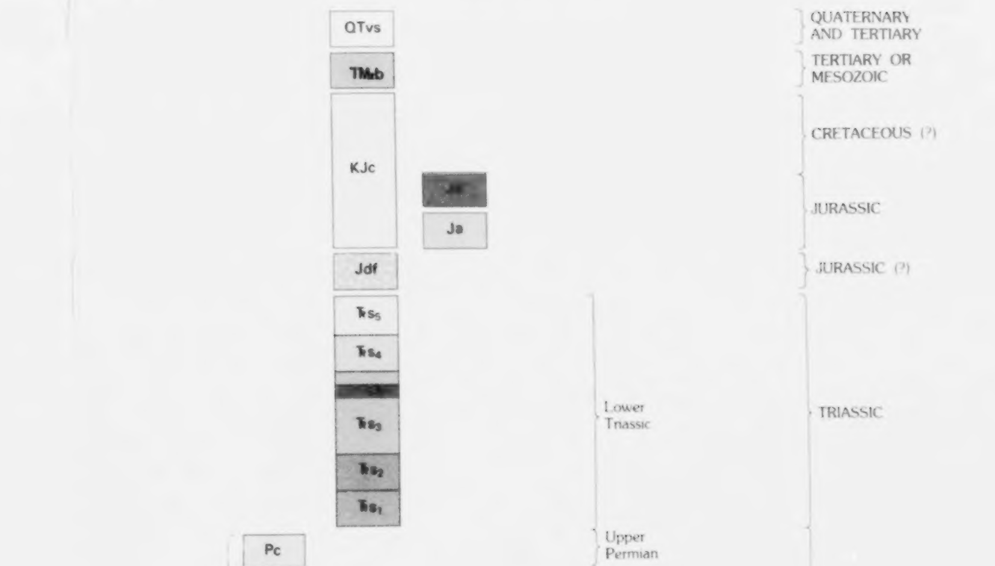
MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1932 (SHEET 1 of 2)



CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

QTvs **Volcanic and sedimentary rocks (Quaternary and Tertiary)**—Pleistocene and Holocene alluvium, talus, and lake deposits; upper Miocene and Pliocene basalt, andesite, pyroclastic rocks, and alluvium (Hall and MacKevett, 1962; Hall, 1971; Larsen, 1979; Schweig, 1983)

TMzb **Breccia (Tertiary or Mesozoic)**—Silicified, hydrothermally altered fault breccia and brecciated skarn mapped locally in the Darwin Hills

KJc **Calc-alkalic granitoid rocks (Cretaceous? and Jurassic)**—Quartz-rich granitoid rocks of calc-alkalic composition, consisting of hornblende-biotite quartz monzonite and subordinate granite exposed along west flank of the Darwin Hills, biotite-bearing leucocratic granite and quartz monzonite exposed in Osborne Canyon and at Zinc Hill in the Argus Range, and small bodies of leucocratic granite exposed near Darwin Canyon. Cut by Jurassic dikes (Jd) in the Darwin Hills and Osborne Canyon. A sample from west flank of the Darwin Hills has yielded a U-Pb age of 156 Ma (sample 78 of Chen and Moore, 1982). Undated body at Zinc Hill lacks crosscutting Jurassic dikes and may be Cretaceous. Previously mapped as Cretaceous(?) quartz monzonite by Hall and MacKevett (1962) and as Jurassic leucocratic quartz monzonite by Hall (1971)

Jd **Dikes (Jurassic)**—Greenish-gray porphyritic dikes of predominantly dioritic composition, averaging about 1.5 m wide, present throughout map area and most abundant in the Argus Range. Only the largest, most continuously exposed dikes are mapped. Interpreted as part of the Independence dike swarm of Moore and Hopson (1961), which has been dated as 148 Ma (Chen and Moore, 1979). Previously mapped as Cretaceous(?) andesite porphyry and diorite dikes by Hall and MacKevett (1962) and Hall (1971)

Ja **Alkalic granitoid rocks (Jurassic)**—Texturally and compositionally heterogeneous, quartz-poor granitoid rocks of alkalic composition, consisting of hornblende-biotite-clinopyroxene quartz monzonite and subordinate monzonite, quartz monzodiorite, and monzodiorite exposed in the Darwin Hills, Santa Rosa Hills, and near Panamint Springs in the Argus Range. Includes small bodies of skarn breccia in the Darwin Hills. Cut by Jurassic dikes (Jd). A sample from the Darwin Hills has yielded a U-Pb age of 174 Ma (sample 77 of Chen and Moore, 1982); a sample from the Argus Range has yielded a K-Ar age of 185 Ma (sample DW–1 of Hall and MacKevett, 1962; age recalculated by Dunne and others, 1978). Considered part of the Hunter Mountain batholith (Dunne, 1986)

Jdf **Darwin Falls pluton (Jurassic?)**—Composite body of cross-intruded gabbro, granodiorite, and subordinate quartz monzonite exposed in the vicinity of Darwin Falls. Primary mineral layering present in gabbro. Characterized by intense saussuritic alteration in most places. Locally cut by Jurassic dikes (Jd). Previously mapped as Cretaceous(?) amphibolite by Hall and MacKevett (1962)

Sedimentary rocks (Lower Triassic)—Heterogeneous sequence composed of mudstone, limestone, sandstone, and siltstone containing Early Triassic conodonts, ammonoids, and pelecypods (Lewis and others, 1983). Previously mapped as part of the Bird Spring(?) Formation by McAllister (1956) and as part of the Owens Valley Formation by Hall and MacKevett (1962). Divided into:

TRs$_5$ **Unit 5**—Light- to medium-gray silty and sandy limestone, locally containing abundant pelecypods. Maximum exposed thickness 50 m, top covered

TRs$_4$ **Unit 4**—Dark-brown, massive siltstone. Thickness 50 m

TRs$_3$ sh **Unit 3**—Medium- to dark-gray, thin-bedded to massive limestone forming cliffs and ridges. Interval of greenish-gray shale (**sh**) 20 m thick present in upper part. Thickness 200 m

TRs$_2$ **Unit 2**—Calcareous mudstone, siliceous mudstone, and limestone. Upper part composed predominantly of yellow, yellowish-brown, and light-brown, thin-bedded calcareous mudstone and calc-hornfels interbedded with medium- to dark-gray, thin- to thick-bedded limestone and limestone conglomerate. Lower part composed predominantly of brown, thin-bedded siliceous mudstone and hornfels that locally contain dark-gray limestone concretions. Ceratitic ammonoids locally abundant. Thickness 500 m

TRs$_1$ **Unit 1**—Tan to gray, mottled, thick-bedded calcareous siltstone, sandstone, and silty to sandy limestone. Thickness 20–100 m

Owens Valley Group (Upper and Lower Permian)—Sandstone, siltstone, limestone, limestone conglomerate, shale, mudstone, conglomeratic mudstone, and conglomerate. Consists of:

Pc **Conglomerate Mesa Formation (Upper Permian)**—Gray to brown, thick-bedded pebble and cobble conglomerate and subordinate fine- to coarse-grained sandstone exposed in the Conglomerate Mesa area. Conglomerate clasts composed of limestone, quartzite, gray chert, and siltstone. Lowermost 5 m locally consists of light-gray, thick-bedded sandy and pebbly limestone. Age based on correlation with type section of the Conglomerate Mesa Formation in the southern Inyo Mountains (Stone and Stevens, 1987), which is dated as late Guadalupian on the basis of ammonoids, brachiopods, and gastropods (Merriam and Hall, 1957; Gordon and Merriam, 1961). Thickness 10–150 m

Sedimentary rocks of Santa Rosa Flat (Lower Permian)—Heterogeneous sequence composed of sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone, exposed in the Conglomerate Mesa area. Divided into:

Psr$_{12}$ **Unit 12**—Yellow, maroon, and greenish-gray shale. Color predominantly yellow in southern exposures and greenish-gray to maroon in northern exposures. Thickness 200–300 m

Psr$_{11}$ **Unit 11**—Brown, yellowish-brown, and reddish-gray, fine- to coarse-grained sandstone, siltstone, and subordinate conglomerate. North and west of Conglomerate Mesa, lower part includes massive limestone conglomerate. Thickness 200–250 m

Psr$_{10}$ **Unit 10**—Medium-gray micritic limestone in which fusulinids, corals, and brachiopods are locally abundant. Dated as Leonardian on the basis of fusulinids (Stone, 1984). Present south and east of Conglomerate Mesa where thickness is 20–40 m

Psr$_9$ **Unit 9**—Yellow to light-gray shale. Color predominantly yellow in southern exposures and light gray in northern exposures. North of Conglomerate Mesa, includes minor bioclastic limestone containing Leonardian fusulinids (Magginetti and others, 1988). Thickness 150–300 m

Psr$_8$ **Unit 8**—Medium- to dark-gray, thin- to thick-bedded, silty bioclastic limestone and limestone conglomerate, interbedded with varying amounts of gray to maroon calcareous shale and siltstone. Graded bedding and Bouma sequences common except in uppermost part of unit and in northern exposures. Fusulinids, corals, and other marine fossils abundant. Dated as latest Wolfcampian to Leonardian on the basis of fusulinids (Stone, 1984; Magginetti and others, 1988). Thickness ranges from 50 m north of Conglomerate Mesa to at least 1,000 m south of Conglomerate Mesa

Psr$_7$ **Unit 7**—Light-gray, massive echinodermal limestone that locally contains fusulinids and brachiopods. Dated as latest Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east and north of Conglomerate Mesa where thickness is 20–100 m

Psr$_6$ ls **Unit 6**—Brown to yellowish-brown, thin- to thick-bedded, very fine to fine-grained sandstone, calcareous sandstone, and siltstone, and medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate in which fusulinids and other marine fossils are abundant. Contains marker beds of limestone and limestone conglomerate (**ls**) 1–5 m thick. Dated as late Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present south and east of Conglomerate Mesa where thickness is 350–600 m

Psr$_5$ **Unit 5**—Dark-gray micritic limestone and subordinate brown to yellowish-brown siltstone and pink shale. Present east of Conglomerate Mesa where thickness is 150 m

Psr$_4$ ls **Unit 4**—Brown to yellowish-brown sandstone, calcareous sandstone, siltstone, and shale; medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate; and minor pink conglomeratic mudstone. Graded bedding and Bouma sequences common. Fusulinids, corals, and other marine fossils abundant in limestone, limestone conglomerate, and conglomeratic mudstone. Contains marker beds of limestone, limestone conglomerate, and conglomeratic mudstone (**ls**) 1–10 m thick. Dated as middle to late Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 450–650 m

Psr$_3$ **Unit 3**—Light- to medium-gray bioclastic limestone and limestone conglomerate that contains abundant fusulinids. Consists of a single graded bed. Dated as middle Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 20 m

Psr$_2$ **Unit 2**—Brown, thick-bedded, very fine grained sandstone and siltstone. Present east of Conglomerate Mesa where thickness is 150–250 m

Psr$_1$ **Unit 1**—Yellowish-brown to brown, thin-bedded calcareous siltstone and shale, interbedded with subordinate medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate. Graded bedding and Bouma sequences present. Fusulinids and corals locally present in limestone. Dated as middle Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east of Conglomerate Mesa where thickness is 380 m with base covered

Darwin Canyon Formation (Lower Permian)—Sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone, exposed in the Darwin Hills, Darwin Canyon area, and Argus Range. Consists of:

Panamint Springs Member—Sandstone, siltstone, and minor limestone. Divided into:

Pdpu ls **Upper part**—Brown to reddish-brown, thin-bedded, very fine grained sandstone and siltstone, interbedded with subordinate medium-gray, fine-grained limestone. Graded bedding and Bouma sequences present. In the Argus Range, contains interval of fine-grained limestone (**ls**) approximately 50 m thick. A few beds in lowermost 150 m contain late Wolfcampian fusulinids; uppermost part may be Leonardian in age (Stone and others, 1987; Magginetti and others, 1988). Maximum exposed thickness 1,000 m, top eroded or covered

Pdpl **Lower part**—Medium- to dark-gray limestone, predominantly fine grained; subordinate pink shale and brown, very fine grained sandstone and siltstone. Contains late Wolfcampian fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 30–100 m

Millers Spring Member—Sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone. Divided into:

Pdmu ls **Upper part**—Brown, medium- to thick-bedded, very fine to fine-grained sandstone and siltstone; medium- to dark-gray, predominantly thick-bedded and massive bioclastic limestone and limestone conglomerate; gray, tan, and pink calcareous shale; and minor pink conglomeratic mudstone. Graded bedding and Bouma sequences common in limestone and limestone conglomerate; sandstone beds commonly crosslaminated. Fusulinids, corals, and other marine fossils abundant in limestone, limestone conglomerate, and conglomeratic mudstone. Where metamorphosed, as in the southern Darwin Hills, consists of quartzite, calc-hornfels, and marble. Contains marker beds of limestone, limestone conglomerate, and conglomeratic mudstone 1–10 m thick, and mappable groups of such beds (**ls**) as thick as 100 m. Dated as middle and late Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 300–400 m. Equivalent to units 3–7 of the Millers Spring Member of Stone and others (1987)

Pdmm **Middle part**—Limestone, limestone conglomerate, conglomeratic mudstone, and siltstone. In Darwin Canyon and the Argus Range, consists of, in ascending order, 20–30 m of medium- to dark-gray, thick-bedded bioclastic limestone, limestone conglomerate, and siltstone; 15–25 m of light-gray to grayish-orange, massive conglomeratic mudstone that contains limestone clasts as much as 1 m in diameter; and as much as 50 m of light-gray, thin-bedded siltstone. Fusulinids, corals, and other marine fossils abundant in limestone and conglomeratic mudstone. Where metamorphosed in the southern Darwin Hills, consists of a single bed of light-gray conglomeratic marble about 10 m thick. Dated as middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Equivalent to unit 2 of the Millers Spring Member of Stone and others (1987)

Pdml **Lower part**—Brown, thick-bedded, very fine grained sandstone and siltstone. Beds commonly crosslaminated. Thickness 120 m. Equivalent to unit 1 of the Millers Spring Member of Stone and others (1987)

Po lscg **Osborne Canyon Formation (Lower Permian)**—Gray to maroon, thin-bedded to massive calcareous mudstone, medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate, and light-brown to gray, plane-laminated calcareous siltstone, exposed in the Darwin Hills, Argus Range, and Santa Rosa Hills. Dark-gray, subspherical limestone concretions common in mudstone. Graded bedding and Bouma sequences present. Limestone conglomerate (**lscg**) locally present in lowermost part. Fusulinids and corals abundant in limestone and limestone conglomerate. Dated as early and middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 100–400 m in the Argus Range, 600 m in the Darwin Hills, and 300 m in the Santa Rosa Hills where top is covered

Ps **Sedimentary rocks (Lower Permian)**—Brown to yellowish-brown calcareous sandstone, siltstone, shale, and mudstone, and medium- to dark-gray bioclastic limestone and limestone conglomerate, exposed in the Talc City Hills and southwestern Darwin Hills. Limestone and limestone conglomerate contain middle to late Wolfcampian corals and fusulinids. May be equivalent to parts of the Osborne Canyon Formation, Millers Spring Member of the Darwin Canyon Formation, and units 1–6 of the sedimentary rocks of Santa Rosa Flat. Previously mapped as the Keeler Canyon and Owens Valley Formations by Hall and MacKevett (1962)

PIPk **Keeler Canyon Formation (Lower Permian to Lower Pennsylvanian)**—Medium- to dark-gray, thin- to thick-bedded, silty and sandy calcarenitic and bioclastic limestone exposed in the Conglomerate Mesa area, Talc City Hills, and western Darwin Hills. Characterized by graded bedding, Bouma sequences, and abundant fusulinids. Tan, thin-bedded calcareous siltstone present in lower part. Lowermost 10 to 30 m consists of medium- to dark-gray, thin- to thick-bedded micritic limestone containing small spherical nodules of dark-gray chert ("golfball" horizon). Unit age in this area is considered to range into the Early Pennsylvanian based on lithologic correlation of its lower cherty limestone part with the Tihvipah Limestone (see Stone and others, 1987). Thickness 430–600 m in the Conglomerate Mesa area and 500 m in the Talc City and Darwin Hills where top is covered

IPs **Sedimentary rocks (Upper? and Middle Pennsylvanian)**—Lenticular unit of calcareous and siliceous rocks that underlies the Osborne Canyon Formation in the southern Darwin Hills. Consists of 15 m of massive limestone conglomerate overlain by 50 m of gray to brown, thin-bedded, silicified limestone and siltstone, and minor bioclastic limestone. Conglomerate in lower part composed exclusively of clasts derived from the Santa Rosa Hills Limestone. Unit appears to occupy a channel that cuts out the Tihvipah Limestone, the Indian Springs Formation of Webster and Lane (1967), and the uppermost part of the Santa Rosa Hills Limestone. Matrix of basal conglomerate contains Middle Pennsylvanian fusulinids (Moffitt, 1978)

IPt **Tihvipah Limestone (Middle and Lower Pennsylvanian)**—Medium- to dark-gray, thin- to thick-bedded, cherty micritic limestone exposed mainly in the Darwin Hills, Argus Range, and Santa Rosa Hills. Contains abundant nodules, lenses, and thin beds of dark-gray chert; pebbly micritic limestone present locally. In the southern Darwin Hills and northern Santa Rosa Hills, lowermost part contains a thin zone of phosphate-pebble conglomerate. Previously mapped as part of the Keeler Canyon Formation by Hall and MacKevett (1962) and Hall (1971). Thickness 50–120 m in most areas and 250–300 m on east side of the Argus Range

Mi **Indian Springs Formation of Webster and Lane (1967) (Upper Mississippian)**—Quartzite, siltstone, and minor limestone that underlies the Tihvipah Limestone in the southern Darwin Hills and Santa Rosa Hills. Late Mississippian brachiopods present in the Santa Rosa Hills (M. Gordon, Jr., written commun., 1983). Previously mapped as the Rest Spring Shale by Hall and MacKevett (1962) in the Santa Rosa Hills. Thickness 10–30 m

Mr **Rest Spring Shale (Upper Mississippian)**—Dark-brown to black shale exposed in the Conglomerate Mesa area, Talc City Hills, and western Darwin Hills. Locally altered to green, yellow, or black andalusite hornfels. Thickness 50–200 m

Ms **Santa Rosa Hills Limestone (Upper Mississippian)**—Light- to very light-gray, thick-bedded, fine- to coarse-grained echinodermal limestone exposed mainly in the Darwin Hills, Argus Range, and Santa Rosa Hills. Contains sparse nodular gray chert. Named by Dunne and others (1981) for rocks previously mapped as the Lee Flat Limestone by Hall and MacKevett (1962). Late Mississippian (Meramecian) foraminifers and conodonts present in the Santa Rosa Hills (Dunne and others, 1981; Klingman, 1987). Thickness 80–100 m in the southern Darwin Hills and Santa Rosa Hills, and 200–300 m in the Argus Range

Perdido Formation (Upper and Lower Mississippian)—Limestone, siliceous limestone, siltstone, and chert. Unit age in this area is considered to range into the Early Mississippian based on conodonts from the limestone (lower) member (see below). Consists of:

Mps **Siltstone member (Upper Mississippian)**—Light- to medium-brown, platy-weathering siltstone exposed in the Conglomerate Mesa area and Talc City Hills. Interbedded in upper part with thin graded beds of medium-gray, bioclastic limestone. Correlated with upper part of type section of the Perdido Formation in the Cottonwood Mountains (northern Panamint Range) (McAllister, 1952). Thickness 50–75 m

Mpl **Limestone member (Upper and Lower Mississippian)**—Medium- to dark-gray, thin- to medium-bedded, fine-grained limestone interbedded with abundant brown-weathering siliceous limestone and chert, exposed mainly in the Argus Range, Darwin Hills, and Santa Rosa Hills. Early Mississippian (Osagean) conodonts present in the Argus Range; Late Mississippian (Meramecian) conodonts present in the hills east of Conglomerate Mesa (Klingman, 1987). Includes the Lee Flat Limestone Member of the Perdido Formation as used by Dunne and others (1981). Correlated with lower part of type section of the Perdido Formation in the Cottonwood Mountains (northern Panamint Range) (McAllister, 1952). Thickness 450 m in the Santa Rosa Hills, and 400 m in the southern Darwin Hills with base covered

Msp **Santa Rosa Hills Limestone (Upper Mississippian) and Perdido Formation (Upper and Lower Mississippian), undivided**—Structurally complex limestone outcrops in the Santa Rosa Hills. Perdido Formation here consists only of its limestone (lower) member

Mpt **Perdido Formation (Upper and Lower Mississippian) and Tin Mountain Limestone (Lower Mississippian), undivided**—Mapped primarily in the Argus Range where thickness is 250 m. Perdido Formation here consists only of its limestone (lower) member

Mt **Tin Mountain Limestone (Lower Mississippian)**—Medium- to dark-gray, thin- to medium-bedded, fine-grained limestone containing gray to black chert lenses and nodules. Brachiopods and corals locally abundant. Thickness 100–130 m

MDc **Carbonate rocks (Mississippian and (or) Devonian)**—Imprecisely identified outcrops of limestone and marble in the western Darwin Hills and near Zinc Hill in the Argus Range. May include parts of the Santa Rosa Hills Limestone, limestone member of the Perdido Formation, Tin Mountain Limestone, and Lost Burro Formation

Dl **Lost Burro Formation (Upper and Middle Devonian)**—Light- to dark-gray, thick-bedded, fine-grained dolomite and medium-gray, fine-grained limestone. Lowermost 20 m consists of fine-grained sandstone; uppermost few meters consist of orthoquartzite. Massive stromatoporoids and *Amphipora* locally abundant. Thickness 400 m

DSh **Hidden Valley Dolomite (Lower Devonian to Lower Silurian)**—Light-gray, massive, fine-grained dolomite. Dark-gray interval present in lower part. Thickness 300 m

SOes **Ely Springs Dolomite (Lower Silurian and Upper Ordovician)**—Dark-gray, thick-bedded, fine-grained dolomite interbedded with thin lenses of black chert and light- to medium-gray, thin-bedded, non-cherty, fine-grained dolomite. Age based on presence of Late Ordovician and Early Silurian conodonts in the Ely Springs Dolomite in the southern Inyo Mountains (Miller, 1975). Thickness 250 m

Oe **Eureka Quartzite (Middle Ordovician)**—Light-gray, vitreous, thick-bedded to massive, medium-grained orthoquartzite. Lower part brown weathering. Thickness 100 m

Ob **Badger Flat Limestone (Middle Ordovician)**—Light- to dark-gray, thick-bedded, fine-grained dolomite interbedded with subordinate medium-gray limestone in lowermost part. Previously mapped as unit d of the Pogonip Group by Hall and MacKevett (1962). Thickness 200 m

Oa **Al Rose Formation (Lower Ordovician)**—Brown, thin-bedded and irregularly bedded siliceous mudstone containing thin layers and small eyes of light-gray dolomite and medium-gray limestone; minor light-gray, thick-bedded dolomite. Previously mapped as unit c of the Pogonip Group by Hall and MacKevett (1962). Thickness 100 m

Єt **Tamarack Canyon Dolomite (Upper Cambrian)**—Light- to dark-gray, thick-bedded, fine-grained dolomite, commonly exhibiting a splotchy appearance from a distance. Upper part contains thin, irregular beds of siliceous mudstone like that in the Al Rose Formation. Large dome-shaped stromatolites common in upper part. Previously mapped as units a and b of the Pogonip Group by Hall and MacKevett (1962). Maximum exposed thickness 250 m

Contact—Showing dip (inclined, vertical, and overturned); dotted where concealed

Fault—Showing dip; bar and ball on downthrown side; dashed where approximately located; dotted where concealed; queried where inferred

Fault—Showing relative horizontal movement; dotted where concealed

Thrust or reverse fault—Showing dip; sawteeth on upper plate; dashed where approximately located; dotted where concealed

Surficial normal fault or slide surface—Showing dip; hachures on downthrown block; dashed where approximately located

Shear zone in granitoid rocks—Showing dip

Anticline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Overturned anticline—Showing trace and dip of axial plane and bearing and plunge of axis; dashed where approximately located

Antiform in overturned beds—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located

Overturned antiform in overturned beds—Showing trace of axial plane

Syncline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Overturned syncline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Synform in overturned beds—Showing trace of axial plane and plunge of axis

Overturned synform in overturned beds—Showing trace of axial plane

Minor anticline—Showing plunge where known

Minor antiform in overturned beds—Showing plunge where known

Minor syncline—Showing plunge where known

Minor synform in overturned beds—Showing plunge where known

Strike and dip of beds
- Inclined
- Vertical
- Horizontal
- Overturned

Strike and dip of foliation
- Inclined
- Vertical

•50 **Fossil locality**—Numbers refer to table 1

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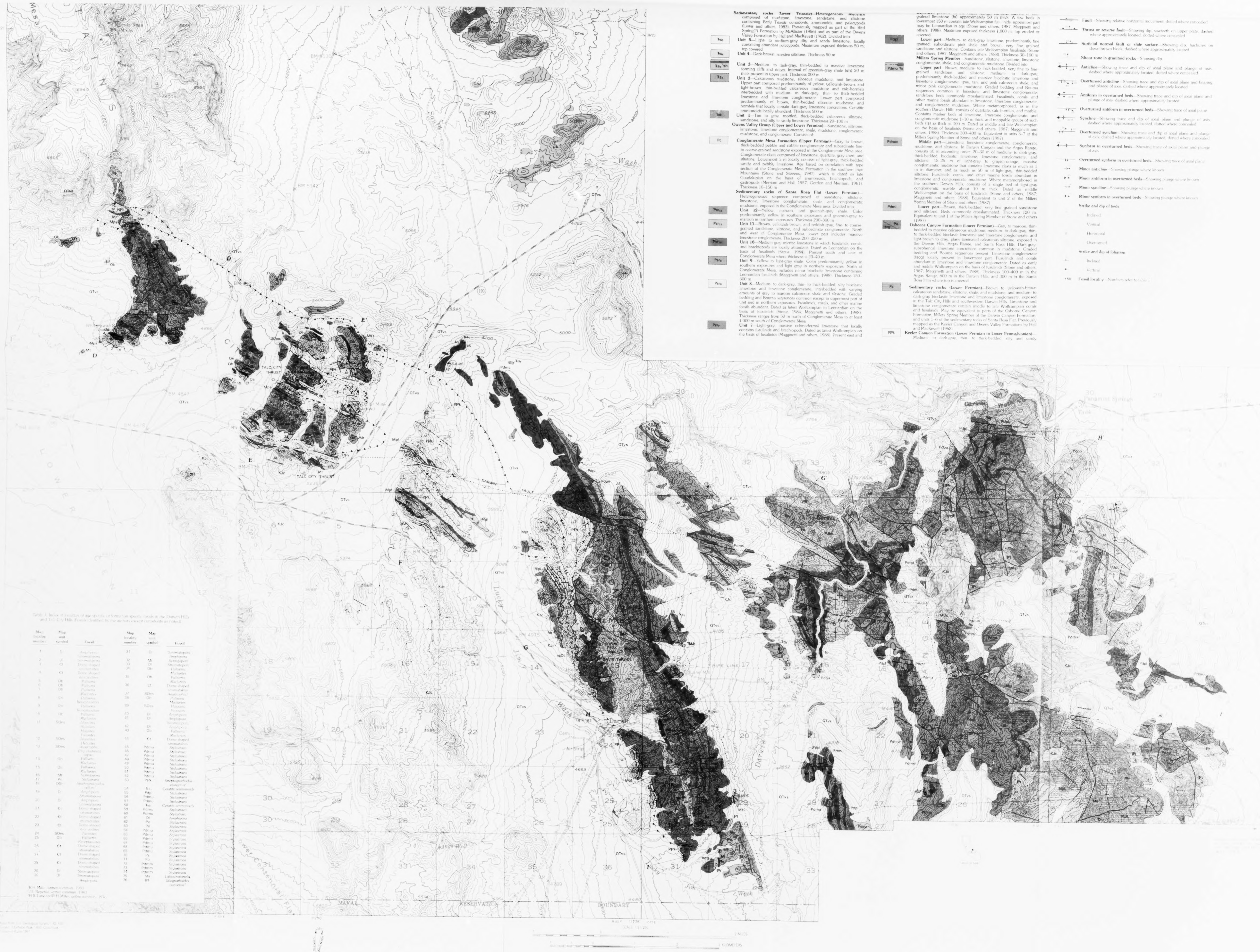


Sedimentary rocks (Lower Triassic)—Heterogeneous sequence composed of mudstone, limestone, sandstone, and siltstone containing Early Triassic conodonts, ammonoids, and pelecypods (Lewis and others, 1983). Previously mapped as part of the Bird Spring(?) Formation by McAllister (1956) and as part of the Owens Valley Formation by Hall and MacKevett (1962). Divided into:

TRs$_5$ **Unit 5**—Light- to medium-gray silty and sandy limestone, locally containing abundant pelecypods. Maximum exposed thickness 50 m; top covered

TRs$_4$ **Unit 4**—Dark-brown, massive siltstone. Thickness 50 m

TRs$_3$ sh **Unit 3**—Medium- to dark-gray, thin-bedded to massive limestone forming cliffs and ridges. Interval of greenish-gray shale (**sh**) 20 m thick present in upper part. Thickness 200 m

TRs$_2$ **Unit 2**—Calcareous mudstone, siliceous mudstone, and limestone. Upper part composed predominantly of yellow, yellowish-brown, and light-brown, thin-bedded calcareous mudstone and calc-hornfels interbedded with medium- to dark-gray, thin- to thick-bedded limestone and limestone conglomerate. Lower part composed predominantly of brown, thin-bedded siliceous mudstone and hornfels that locally contain dark-gray limestone concretions. Ceratitic ammonoids locally abundant. Thickness 500 m

TRs$_1$ **Unit 1**—Tan to gray, mottled, thick-bedded calcareous siltstone, sandstone, and silty to sandy limestone. Thickness 20–100 m

Owens Valley Group (Upper and Lower Permian)—Sandstone, siltstone, limestone, limestone conglomerate, shale, mudstone, conglomeratic mudstone, and conglomerate. Consists of:

Pc **Conglomerate Mesa Formation (Upper Permian)**—Gray to brown, thick-bedded pebble and cobble conglomerate and subordinate fine- to coarse-grained sandstone exposed in the Conglomerate Mesa area. Conglomerate clasts composed of limestone, quartzite, gray chert, and siltstone. Lowermost 5 m locally consists of light-gray, thick-bedded sandy and pebbly limestone. Age based on correlation with type section of the Conglomerate Mesa Formation in the southern Inyo Mountains (Stone and Stevens, 1987), which is dated as late Guadalupian on the basis of ammonoids, brachiopods, and gastropods (Merriam and Hall, 1957; Gordon and Merriam, 1961). Thickness 10–150 m

Sedimentary rocks of Santa Rosa Flat (Lower Permian)—Heterogeneous sequence composed of sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone, exposed in the Conglomerate Mesa area. Divided into:

Psr$_{12}$ **Unit 12**—Yellow, maroon, and greenish-gray shale. Color predominantly yellow in southern exposures and greenish-gray to maroon in northern exposures. Thickness 200–300 m

Psr$_{11}$ **Unit 11**—Brown, yellowish-brown, and reddish-gray, fine- to coarse-grained sandstone, siltstone, and subordinate conglomerate. North and west of Conglomerate Mesa, lower part includes massive limestone conglomerate. Thickness 200–250 m

Psr$_{10}$ **Unit 10**—Medium-gray micritic limestone in which fusulinids, corals, and brachiopods are locally abundant. Dated as Leonardian on the basis of fusulinids (Stone, 1984). Present south and east of Conglomerate Mesa where thickness is 20–40 m

Psr$_9$ **Unit 9**—Yellow to light-gray shale. Color predominantly yellow in southern exposures and light gray in northern exposures. North of Conglomerate Mesa, includes minor bioclastic limestone containing Leonardian fusulinids (Magginetti and others, 1988). Thickness 150–300 m

Psr$_8$ **Unit 8**—Medium- to dark-gray, thin- to thick-bedded, silty bioclastic limestone and limestone conglomerate, interbedded with varying amounts of gray to maroon calcareous shale and siltstone. Graded bedding and Bouma sequences common except in uppermost part of unit and in northern exposures. Fusulinids, corals, and other marine fossils abundant. Dated as latest Wolfcampian to Leonardian on the basis of fusulinids (Stone, 1984; Magginetti and others, 1988). Thickness ranges from 50 m north of Conglomerate Mesa to at least 1,000 m south of Conglomerate Mesa

Psr$_7$ **Unit 7**—Light-gray, massive echinodermal limestone that locally contains fusulinids and brachiopods. Dated as latest Wolfcampian on the basis of fusulinids (Magginetti and others, 1988). Present east and

grained limestone (**ls**) approximately 50 m thick. A few beds in lowermost 150 m contain late Wolfcampian fusulinids; uppermost part may be Leonardian in age (Stone and others, 1987; Magginetti and others, 1988). Maximum exposed thickness 1,000 m; top eroded or covered

Pdpl **Lower part**—Medium- to dark-gray limestone, predominantly fine grained; subordinate pink shale and brown, very fine grained sandstone and siltstone. Contains late Wolfcampian fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 30–100 m

Millers Spring Member—Sandstone, siltstone, limestone, limestone conglomerate, shale, and conglomeratic mudstone. Divided into:

Pdmu ls **Upper part**—Brown, medium- to thick-bedded, very fine to fine-grained sandstone and siltstone; medium- to dark-gray, predominantly thick-bedded and massive bioclastic limestone and limestone conglomerate; gray, tan, and pink calcareous shale; and minor pink conglomeratic mudstone. Graded bedding and Bouma sequences common in limestone and limestone conglomerate; sandstone beds commonly crosslaminated. Fusulinids, corals, and other marine fossils abundant in limestone, limestone conglomerate, and conglomeratic mudstone. Where metamorphosed, as in the southern Darwin Hills, consists of quartzite, calc-hornfels, and marble. Contains marker beds of limestone, limestone conglomerate, and conglomeratic mudstone 1–10 m thick, and mappable groups of such beds (**ls**) as thick as 100 m. Dated as middle and late Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 300–400 m. Equivalent to units 3–7 of the Millers Spring Member of Stone and others (1987)

Pdmm **Middle part**—Limestone, limestone conglomerate, conglomeratic mudstone, and siltstone. In Darwin Canyon and the Argus Range, consists of, in ascending order: 20–30 m of medium- to dark-gray, thick-bedded bioclastic limestone, limestone conglomerate, and siltstone; 15–25 m of light-gray to grayish-orange, massive conglomeratic mudstone that contains limestone clasts as much as 1 m in diameter; and as much as 50 m of light-gray, thin-bedded siltstone. Fusulinids, corals, and other marine fossils abundant in limestone and conglomeratic mudstone. Where metamorphosed in the southern Darwin Hills, consists of a single bed of light-gray conglomeratic marble about 10 m thick. Dated as middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Equivalent to unit 2 of the Millers Spring Member of Stone and others (1987)

Pdml **Lower part**—Brown, thick-bedded, very fine grained sandstone and siltstone. Beds commonly crosslaminated. Thickness 120 m. Equivalent to unit 1 of the Millers Spring Member of Stone and others (1987)

Po lscg **Osborne Canyon Formation (Lower Permian)**—Gray to maroon, thin-bedded to massive calcareous mudstone, medium- to dark-gray, thin- to thick-bedded bioclastic limestone and limestone conglomerate, and light-brown to gray, plane-laminated calcareous siltstone, exposed in the Darwin Hills, Argus Range, and Santa Rosa Hills. Dark-gray, subspherical limestone concretions common in mudstone. Graded bedding and Bouma sequences present. Limestone conglomerate (**lscg**) locally present in lowermost part. Fusulinids and corals abundant in limestone and limestone conglomerate. Dated as early and middle Wolfcampian on the basis of fusulinids (Stone and others, 1987; Magginetti and others, 1988). Thickness 100–400 m in the Argus Range, 600 m in the Darwin Hills, and 300 m in the Santa Rosa Hills where top is covered

Ps **Sedimentary rocks (Lower Permian)**—Brown to yellowish-brown calcareous sandstone, siltstone, shale, and mudstone, and medium- to dark-gray bioclastic limestone and limestone conglomerate, exposed in the Talc City Hills and southwestern Darwin Hills. Limestone and limestone conglomerate contain middle to late Wolfcampian corals and fusulinids. May be equivalent to parts of the Osborne Canyon Formation, Millers Spring Member of the Darwin Canyon Formation, and units 1–6 of the sedimentary rocks of Santa Rosa Flat. Previously mapped as the Keeler Canyon and Owens Valley Formations by Hall and MacKevett (1962)

Pℙk **Keeler Canyon Formation (Lower Permian to Lower Pennsylvanian)**—Medium- to dark-gray, thin- to thick-bedded, silty and sandy

Fault—Showing relative horizontal movement; dotted where concealed

Thrust or reverse fault—Showing dip; sawteeth on upper plate; dashed where approximately located; dotted where concealed

Surficial normal fault or slide surface—Showing dip; hachures on downthrown block; dashed where approximately located

Shear zone in granitoid rocks—Showing dip

Anticline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Overturned anticline—Showing trace and dip of axial plane and bearing and plunge of axis; dashed where approximately located

Antiform in overturned beds—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located

Overturned antiform in overturned beds—Showing trace of axial plane

Syncline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Overturned syncline—Showing trace and dip of axial plane and plunge of axis; dashed where approximately located; dotted where concealed

Synform in overturned beds—Showing trace of axial plane and plunge of axis

Overturned synform in overturned beds—Showing trace of axial plane

Minor anticline—Showing plunge where known

Minor antiform in overturned beds—Showing plunge where known

Minor syncline—Showing plunge where known

Minor synform in overturned beds—Showing plunge where known

Strike and dip of beds

- Inclined
- Vertical
- Horizontal
- Overturned

Strike and dip of foliation

- Inclined
- Vertical

• 50 **Fossil locality**—Numbers refer to table 1

Table 1. Index of localities of age-specific or formation-specific fossils in the Darwin Hills and Talc City Hills (Fossils identified by the authors except conodonts as noted)

Map locality number	Map unit symbol	Fossil	Map locality number	Map unit symbol	Fossil
1	Dl	*Amphipora* "*Stromatopora*"	31	Dl	"*Stromatopora*" *Amphipora*
2	Dl	"*Stromatopora*"	32	Mt	*Syringopora*
3	Ꞓt	Dome-shaped stromatolites	33	Dl	"*Stromatopora*"
4	Ꞓt	Dome-shaped stromatolites	34	Ob	*Pallisera* *Maclurites*
5	Ob	*Pallisera*	35	Ob	*Pallisera* *Maclurites*
6	Ob	*Pallisera*	36	Ꞓt	Dome-shaped stromatolites
7	Ob	*Pallisera* *Maclurites*	37	SOes	*Anastrophia?*
8	Ob	*Pallisera* *Receptaculites*	38	Ob	*Pallisera* *Maclurites*
9	Ob	*Pallisera* *Receptaculites*	39	SOes	*Halysites* *Favosites*
10	Ob	*Pallisera* *Maclurites*	40	Dl	*Amphipora*
11	SOes	*Alveolites* *Heliolites* *Halysites* *Favosites*	41	Dl	*Amphipora* "*Stromatopora*"
12	SOes	*Alveolites* *Heliolites*	42	Dl	*Amphipora*
13	SOes	*Anastrophia* *Rhynchotrema capax*	43	Ob	*Pallisera* *Maclurites*
14	Ob	*Pallisera* *Maclurites*	44	Ꞓt	Dome-shaped stromatolites
15	Ob	*Pallisera* *Maclurites*	45	Pdmu	*Stylastraea*
16	Mt	*Syringopora*	46	Pdmu	*Stylastraea*
17	Ps	*Stylastraea*	47	Pdmu	*Stylastraea*
18	DSh	*Spathognathodus celloni*[1]	48	Pdmu	*Stylastraea*
19	Dl	*Amphipora* "*Stromatopora*"	49	Pdmu	*Stylastraea*
20	Dl	*Amphipora* "*Stromatopora*"	50	Pdmu	*Stylastraea*
21	Ꞓt	Dome-shaped stromatolites	51	Pdmu	*Stylastraea*
22	Ꞓt	Dome-shaped stromatolites	52	Pdmu	*Stylastraea*
23	Ꞓt	Dome-shaped stromatolites	53	Pℙk	*Streptognathodus elongatus*[2]
24	SOes	*Favosites*	54	TRs$_1$	Ceratitic ammonoids
25	Ob	*Pallisera* *Receptaculites*	55	Pdpl	*Stylastraea*
26	Ꞓt	Dome-shaped stromatolites	56	Pdmu	*Stylastraea*
27	Ꞓt	Dome-shaped stromatolites	57	Pdmu	*Stylastraea*
28	Ꞓt	Dome-shaped stromatolites	58	TRs$_1$	Ceratitic ammonoids
29	Dl	"*Stromatopora*"	59	Pdmu	*Stylastraea*
30	Dl	"*Stromatopora*" *Amphipora*	60	Pdmu	*Stylastraea*
			61	Dl	*Amphipora*
			62	Po	*Stylastraea*
			63	Po	*Stylastraea*
			64	Pdmu	*Stylastraea*
			65	Pdmu	*Stylastraea*
			66	Pdmu	*Stylastraea*
			67	Pdmu	*Stylastraea*
			68	Pdmu	*Stylastraea*
			69	Pdmu	*Stylastraea*
			70	Ps	*Stylastraea*
			71	Po	*Stylastraea*
			72	Pdmm	*Stylastraea*
			73	Pdmm	*Stylastraea*
			74	Pdmm	*Stylastraea*
			75	Ms	*Lithostrotionella*
			76	ℙt	*Idiognathoides convexus*[3]

[1] R.H. Miller, written commun., 1980

[2] J.E. Repetski, written commun., 1983

[3] H.R. Lane and R.H. Miller, written commun., 1976

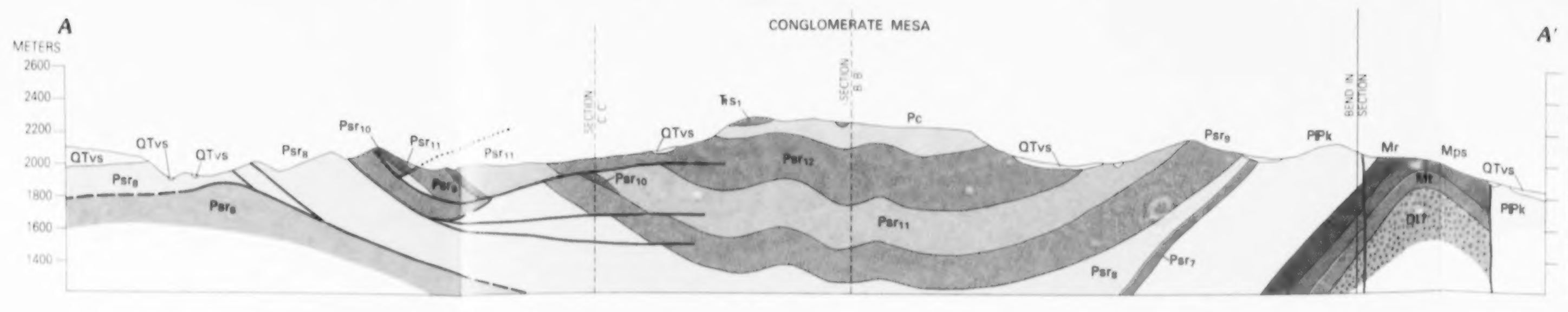
GEOLOGIC MAP OF PALEOZOIC AND MESOZOIC ROCKS IN PARTS OF THE DARWIN AND ADJACENT QUADRANGLES, INYO COUNTY, CALIFORNIA

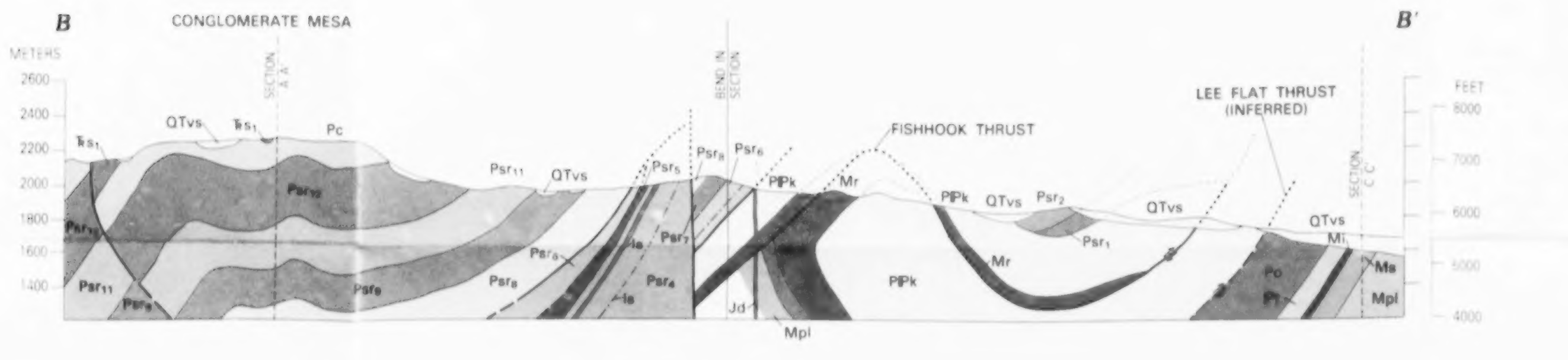
By

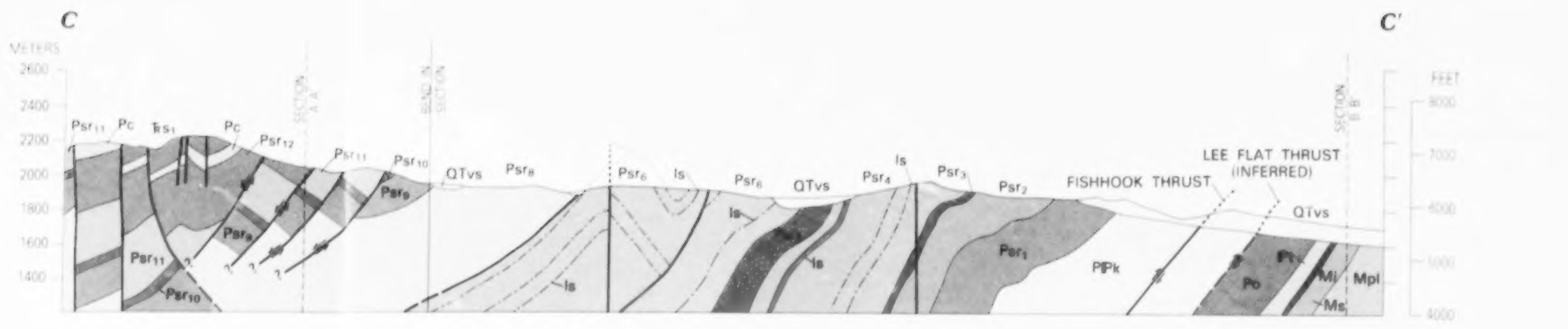
Paul Stone, George C. Dunne, Calvin H. Stevens, and Rachel M. Gulliver

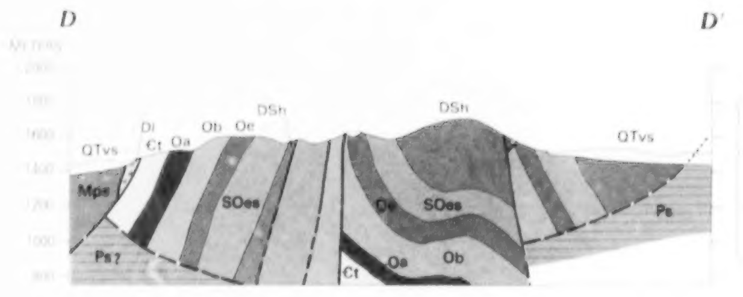
1989

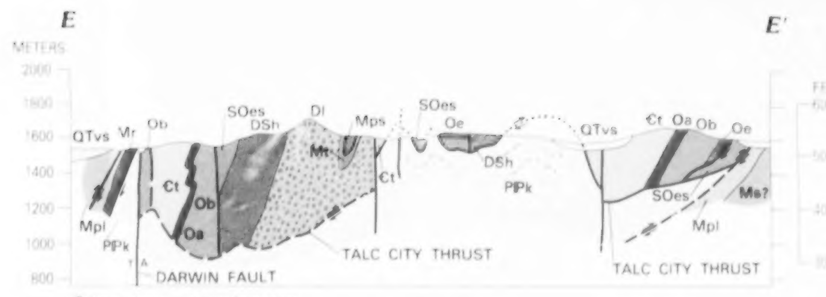
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

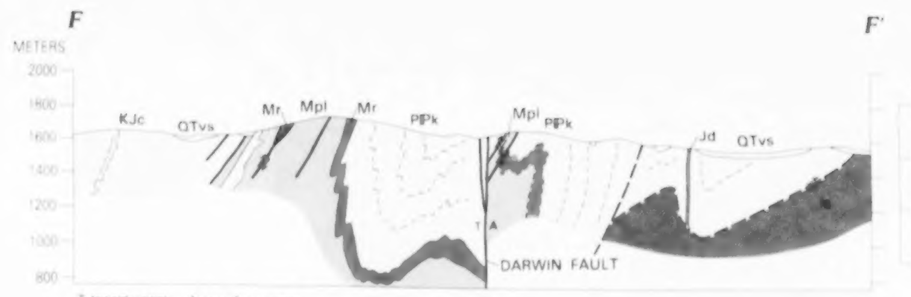


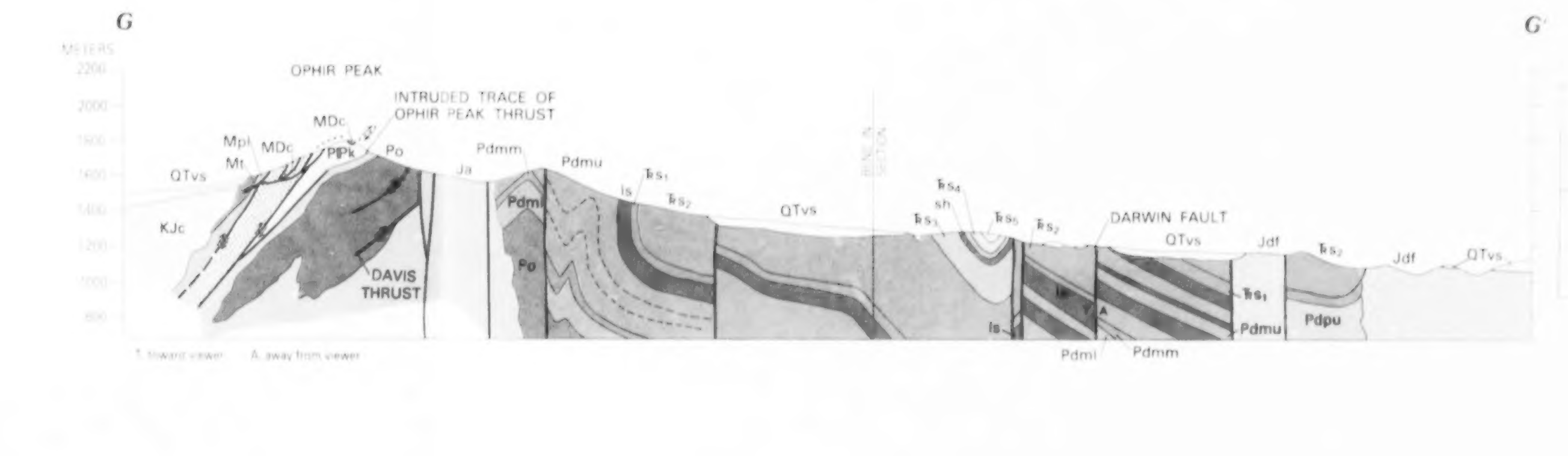


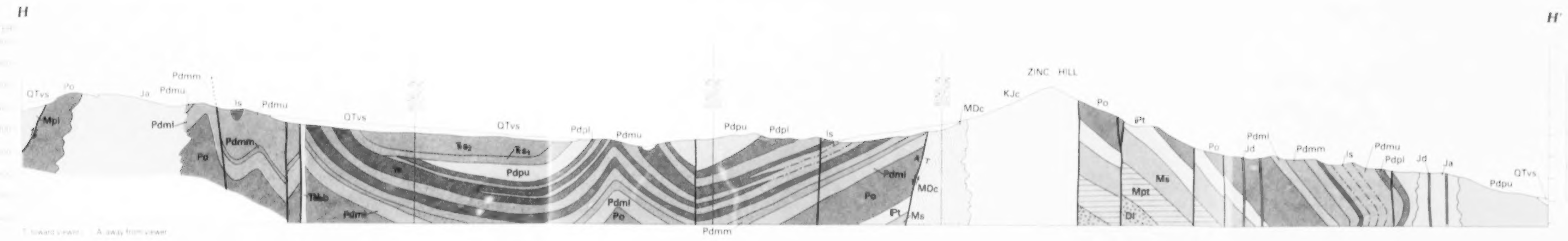


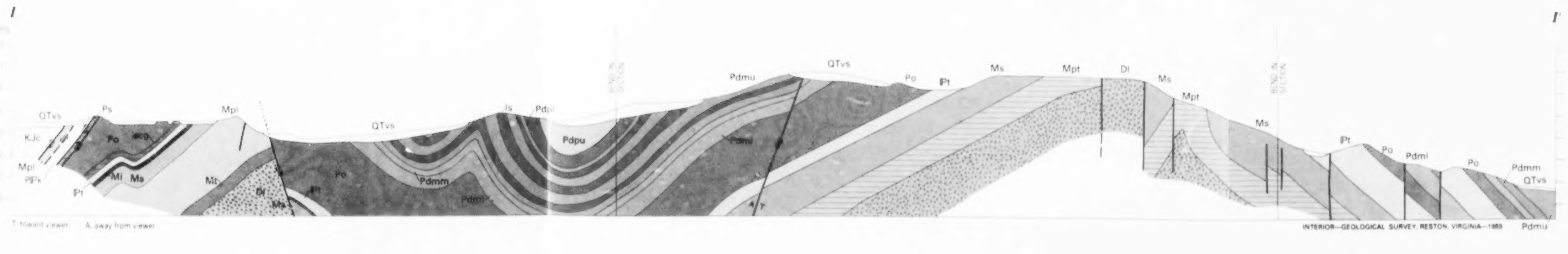







G
G'
OPHIR PEAK
INTRUDED TRACE OF OPHIR PEAK THRUST
DAVIS THRUST
DARWIN FAULT
QTvs
T, toward viewer; A, away from viewer





INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1989

CROSS SECTIONS TO ACCOMPANY

GEOLOGIC MAP OF PALEOZOIC AND MESOZOIC ROCKS IN PARTS OF THE DARWIN AND ADJACENT QUADRANGLES, INYO COUNTY, CALIFORNIA

By

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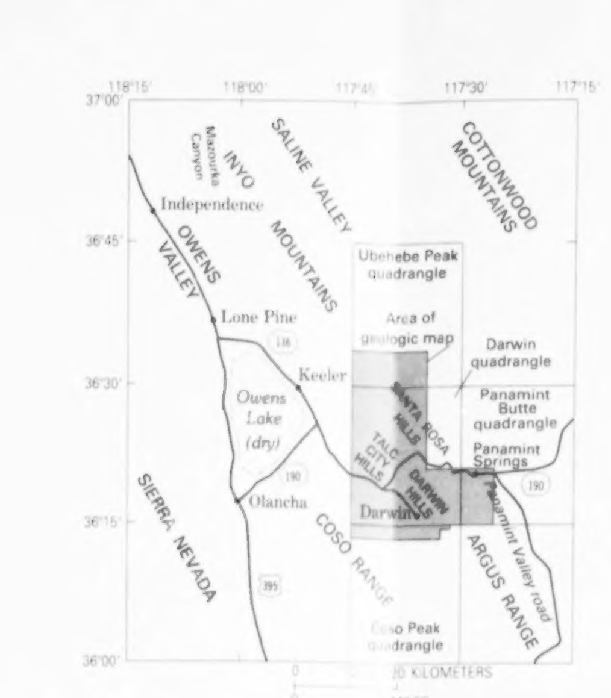

Figure 1. Location of map area in southeastern California showing names of 15-minute quadrangles covering the area.

INTRODUCTION

This map depicts the geology of Paleozoic and Mesozoic rocks exposed in the southeasternmost Inyo Mountains (Conglomerate Mesa area), the Santa Rosa Hills, the Talc City Hills, the Darwin Hills, the Darwin Canyon area, and the north end of the Argus Range, Inyo County, Calif. (fig. 1). The map area includes the majority of the Darwin 15-minute quadrangle, the southwest corners of the Ubehebe Peak and Panamint Butte quadrangles, and the northernmost part of the Coso Peak quadrangle. The map area contains an unusually complex Cambrian to Triassic stratigraphic record that has numerous implications for the paleogeography of the southwest end of the Cordilleran miogeosynclinal belt, and an excellent record of Mesozoic structural deformation along the east margin of the Sierra Nevada batholith.

Except for the small part that lies within the Coso Peak quadrangle, the map area is covered by existing U.S. Geological Survey geologic maps. McAllister (1956) mapped the Ubehebe Peak quadrangle; Hall and MacKevett (1962) mapped the Darwin quadrangle; and Hall (1971) mapped the Panamint Butte quadrangle. In addition, Elayer (1974), Moffitt (1978), Werner (1979), and Prevost (1984) mapped parts of the area as the basis for master's theses. The map we present here shows more stratigraphic and structural detail than earlier maps, corrects some previous misinterpretations, and incorporates recent changes in stratigraphic nomenclature. Except for the outlines of isolated granitoid rock outcrops south of the Santa Rosa Hills, which are from Hall and MacKevett (1962), we compiled this map entirely from our own work, including that of Gulliver (1976) and Stone (1984).

GENERAL GEOLOGIC FRAMEWORK

Most of the map area is underlain by sedimentary rocks of Late Cambrian to Early Triassic age. These rocks, which represent the southwesternmost part of the Cordilleran miogeosynclinal belt, consist of limestone, dolomite, shale, quartzose sandstone and siltstone, and minor conglomerate. They are intruded by Jurassic and Cretaceous(?) granitoid rocks that lie along the east margin of the Sierra Nevada batholith. Near intrusive bodies, the sedimentary rocks are strongly metamorphosed and mineralized. The sedimentary rocks are deformed by several generations of faults and folds that developed over much of Mesozoic and perhaps early Cenozoic time. The structurally complex Paleozoic and Mesozoic rocks are unconformably overlain by an extensive cover of flat-lying to gently dipping Tertiary volcanic rocks and by Quaternary alluvium and lake deposits. The Tertiary and older rocks are cut by basin-and-range normal faults of mostly undetermined displacement.

PALEOZOIC AND TRIASSIC STRATIGRAPHY

CAMBRIAN TO DEVONIAN ROCKS

The main exposures of Devonian and older rocks in the map area are in the Talc City Hills, which are underlain largely by rocks we assign to the Upper Cambrian Tamarack Canyon Dolomite, the Lower Ordovician Al Rose Formation, the Middle Ordovician Badger Flat Limestone and Eureka Quartzite, the Upper Ordovician and Lower Silurian Ely Springs Dolomite, the Lower Silurian to Lower Devonian Hidden Valley Dolomite, and the Middle and Upper Devonian Lost Burro Formation. The Hidden Valley Dolomite also is exposed in the northwestern Darwin Hills, and the Lost Burro Formation is exposed in the Argus Range, northwestern Darwin Hills, and Santa Rosa Hills. The Devonian and older rocks within the area represent deposition in various shallow-marine environments of the Cordilleran miogeocline (Stevens, 1986).

For the most part, the formation names we use for the Devonian and older rocks are the same as those used by Hall and MacKevett (1962), Hall (1971), and other previous workers. The only difference is that we reassign rocks mapped as the Pogonip Group by Hall and MacKevett (1962) to the Tamarack Canyon Dolomite, the Al Rose Formation, and the Badger Flat Limestone. These three formations have been traced discontinuously into the Talc City Hills from their type sections at Mazourka Canyon in the Inyo Mountains (fig. 1), but with the following changes in lithology (Stevens, 1986): (1) the Tamarack Canyon Dolomite in the Talc City Hills includes one or two thin intervals of siliceous mudstone not present at Mazourka Canyon, and contains lighter-colored zones and less chert than at Mazourka Canyon, (2) thin limestone beds in the predominantly siliceous Al Rose Formation at Mazourka Canyon are replaced by dolomite in the Talc City Hills, and (3) the Badger Flat Limestone is composed primarily of limestone at Mazourka Canyon and dolomite in the Talc City Hills.

Fossils have been useful in assigning the various dolomite units in the Talc City Hills to the appropriate formations (table 1). (1) We have found dome-shaped stromatolites only in the Tamarack Canyon Dolomite. (2) As noted by Hall and MacKevett (1962), the Badger Flat Limestone (their unit d of the Pogonip Group) commonly contains the large gastropods *Palliseria* and *Maclurites* and the sponge-like fossil *Receptaculites*. (3) The Ely Springs Dolomite locally contains a variety of tabulate corals (*Alveolites*, *Heliolites*, *Halysites*, *Favosites*), occasional rugose corals, and brachiopods (*Anastrophia*, *Rhynchotrema*). (4) The Hidden Valley Dolomite, although largely unfossiliferous, has yielded age-diagnostic conodonts at one locality (locality 18, table 1). (5) The Lost Burro Formation, which consists of both limestone and dolomite, is distinguished by the presence of massive stromatoporoids listed in table 1 as "*Stromatopora*" and the stemmed stromatoporoid *Amphipora*.

MISSISSIPPIAN ROCKS

Mississippian rocks are exposed at several localities in the Darwin quadrangle and vicinity, including the hills north and east of Conglomerate Mesa, the Santa Rosa Hills, the Talc City Hills, the Darwin Hills, and the Argus Range. Throughout the area, these rocks conformably overlie the Devonian Lost Burro Formation and are conformably or disconformably overlain by Pennsylvanian rocks.

Major lateral facies changes in the Mississippian rocks from southeast to northwest within the map area are reflected in the stratigraphic nomenclature. Mississippian rocks in the southeastern part of the area (Argus Range, southern Darwin Hills, and Santa Rosa Hills) predominantly consist of shelf limestone assigned to three widespread units, the Tin Mountain Limestone, the limestone member of the Perdido Formation, and the Santa Rosa Hills Limestone (Stevens and others, 1979; Dunne and others 1981; Stevens, 1986). In the Santa Rosa Hills and southern Darwin Hills, the Santa Rosa Hills Limestone is overlain by a thin unit of Upper Mississippian quartzite and shale that we assign to the Indian Springs Formation of Webster and Lane (1967). A different Mississippian sequence is present in the northwestern part of the area (hills north of Conglomerate Mesa), where shelf limestone assigned to the Tin Mountain Limestone is overlain by Upper Mississippian siliciclastic rocks assigned to the siltstone member of the Perdido Formation and the Rest Spring Shale. These siliciclastic rocks represent a relatively deep-water (slope or basin) facies (Stevens and others, 1979; Stevens, 1986). The contact between the Tin Mountain Limestone and siltstone facies of the Perdido Formation in the northwestern sequence is considered to be a disconformity spanning the time during which the limestone member of the Perdido Formation was deposited to the southeast; the siltstone member of the Perdido Formation and the Rest Spring Shale are considered to be approximately coeval with the Santa Rosa Hills Limestone and Indian Springs Formation, respectively (Stevens and others, 1979; Dunne and others, 1981; Stevens, 1986). A variant of the northwestern Mississippian sequence is represented in the hills east of Conglomerate Mesa and in parts of the Talc City Hills, where Upper Mississippian limestone assigned to the limestone member of the Perdido Formation is present between the Tin Mountain Limestone and the siltstone member of the Perdido Formation.

In the Talc City Hills and Darwin Hills, Mesozoic thrust faults juxtapose the northwestern and southeastern Mississippian sequences described above with a third, lithologically transitional sequence that consists of the Tin Mountain Limestone, the limestone member of the Perdido Formation, and a thin shale unit assigned to the Rest Spring Shale. The upper part of the limestone member of the Perdido Formation in this transitional sequence is inferred to be coeval with the Santa Rosa Hills Limestone and the siltstone member of the Perdido Formation.

PENNSYLVANIAN AND PERMIAN ROCKS

Pennsylvanian and Permian rocks underlie most of the Conglomerate Mesa area, parts of the Santa Rosa Hills and the Talc City Hills, and most of the Darwin Hills, Darwin Canyon area, and Argus Range. Recent studies have shown that the Pennsylvanian and Permian rocks, like the underlying Mississippian rocks, undergo major lateral facies changes from southeast to northwest within the map area (Stone, 1984; Stone and Stevens, 1984, 1987; Stone and others, 1987). Although previous workers were aware of some of these facies changes, they did not attempt to map the various lithofacies as separate rock units. Hall and MacKevett (1962) and Hall (1971) mapped Pennsylvanian and Permian rocks throughout the area as the Keeler Canyon and Owens Valley Formations, both of which were defined in the Inyo Mountains northwest of the Darwin quadrangle; earlier, McAllister (1956) had mapped the Pennsylvanian and Permian rocks in the Conglomerate Mesa area as part of the Bird Spring(?) Formation. In order to emphasize the lateral facies changes, we distinguish the different facies as separate map units. Stone (1984), Stone and Stevens (1984, 1987), and Stone and others (1987) have discussed the facies changes and the associated variations in stratigraphic nomenclature in detail; we summarize the most important of them here.

We apply the name Keeler Canyon Formation to rocks of Pennsylvanian and earliest Permian age exposed in the northwestern part of the area, specifically in the hills north and east of Conglomerate Mesa, the Talc City Hills, and the west flank of the Darwin Hills. This formation, which overlies the Rest Spring Shale, constitutes a basinal facies consisting mainly of limestone turbidites (Stone, 1984; Stone and Stevens, 1984). A thin basal unit, not mapped separately, consists of gray micritic limestone that contains abundant nodular and lenticular chert. Previous workers have informally referred to this basal unit as the "golfball" horizon. We consider this basal unit equivalent to the Tihvipah Limestone, which was originally defined in the Cottonwood Mountains (northern Panamint Range) by McAllister (1952).

To the southeast, in the Santa Rosa Hills, southern Darwin Hills, and Argus Range, the Pennsylvanian is represented by a thin unit of cherty micritic limestone similar in lithology and age to the basal unit of the Keeler Canyon Formation. We map this unit as the Tihvipah Limestone. This formation, which probably represents an outer-shelf or slope facies, overlies the Indian Springs Formation or the Santa Rosa Hills Limestone and is overlain by Lower Permian rocks that form the basal part of the Owens Valley Group. At most localities, a disconformity representing the Upper Pennsylvanian and part of the Lower Permian separates the Tihvipah Limestone from the Owens Valley Group (Stone, 1984; Stone and Stevens, 1987), and no rocks corresponding either lithologically or temporally to the upper part of the Keeler Canyon Formation (that is, the part of that formation above the basal cherty limestone unit) are present. In the southern Darwin Hills, however, an unnamed thin, channelized sequence of limestone conglomerate, siltstone, and silicified limestone younger than the Tihvipah Limestone and older than the Owens Valley Group may be partly correlative with the upper part of the Keeler Canyon Formation.

The Permian Owens Valley Group, raised from formational rank by Stone and Stevens (1987), is extensively exposed within the map area. Throughout most of the area, the group consists of the Osborne Canyon Formation and the overlying Darwin Canyon Formation, both of which are Early Permian in age (Stone and others, 1987; Magginetti and others, 1988). These two formations are best exposed in Darwin Canyon and the Argus Range where their type sections are located, but also are widespread in the Darwin Hills where they are partially metamorphosed, and the Osborne Canyon Formation is recognized in the Santa Rosa Hills. The Osborne Canyon and Darwin Canyon Formations are composed mainly of siliceous and calcareous turbidites and debris-flow deposits representing slope and basinal environments of deposition. Limestone turbidites and debris-flow deposits in both formations contain fragments of colonial corals including *Stylastraea* (table 1), the presence of which is a reliable aid in distinguishing these formations from the somewhat similar Keeler Canyon Formation, which lacks fragments of this coral.

A somewhat different Permian sequence is present in the Conglomerate Mesa area, where the Owens Valley Group consists of the Upper Permian Conglomerate Mesa Formation (Stone and Stevens, 1987) and a thick sequence of Lower Permian strata which are informally referred to as the sedimentary rocks of Santa Rosa Flat (Stevens and Stone, 1988). The sedimentary rocks of Santa Rosa Flat are divided into twelve numbered units. Units 1–6, Wolfcampian in age, are basinal units consisting largely of calcareous and siliceous turbidites. These units are coeval with parts of the Osborne Canyon and Darwin Canyon Formations and contain similar rock types, but are distinguished from those formations on the basis of numerous litholigic details. Precise lithologic correlations, however, are considered to exist between unit 2 and the lower part of the Millers Spring Member of the Darwin Canyon Formation, and between unit 5 and the lower part of the Panamint Springs Member. Unit 7, latest Wolfcampian in age, is a lens of massive echinodermal limestone that apparently represents a shallow-water depositional setting. Unit 8, Leonardian in age, consists mainly of limestone turbidites but grades upsection and northward into limestone of relatively shallow-water origin. Some rocks in units 7 and 8 may be the same age as parts of the lithologically distinct Panamint Springs Member of the Darwin Canyon Formation. Units 9–12, Leonardian to early Guadalupian(?) in age, consist mainly of shallow-water rocks, and the overlying Conglomerate Mesa Formation of late Guadalupian age consists mainly of nonmarine rocks. Neither units 9–12 nor the Conglomerate Mesa Formation have lithologic or temporal counterparts in the southeastern part of the map area.

Units 1–6 of the sedimentary rocks of Santa Rosa Flat, which are more than 2,000 m thick in the area southeast of Conglomerate Mesa, thin rapidly northward and are absent in the area immediately north and northeast of Conglomerate Mesa. Unit 8, which is at least 1,000 m thick where it overlies unit 6 south and east of Conglomerate Mesa, thins to only about 50 m in the hills north of Conglomerate Mesa where it disconformably overlies the Keeler Canyon Formation. The pronounced lenticularity of these units resulted from northwestward depositional onlap against the Keeler Canyon Formation, which we interpret to have formed the surface of an elevated structural block at the margin of the basin in which the sedimentary rocks of Santa Rosa Flat accumulated (Stevens and Stone, 1988). Part of this onlap is exposed at a hill (elevation 6,719 ft) 3 km east of Conglomerate Mesa, where unit 2 wedges out depositionally along an abutment unconformity with the Keeler Canyon Formation. Our interpretation of this discordant contact differs from that of McAllister (1956), who mapped it as a fault within the Bird Spring(?) Formation.

Although the Owens Valley Group is almost entirely younger than the Keeler Canyon Formation, fossils indicate that the lowermost parts of the Osborne Canyon Formation in the southern Darwin Hills and northern Santa Rosa Hills are equivalent in age to the uppermost part of the Keeler Canyon Formation (Magginetti and others, 1988).

TRIASSIC ROCKS

An unnamed sequence of Lower Triassic marine strata between 800 and 900 m thick is discontinuously exposed from the east flank of the Darwin Hills to Darwin Canyon, where it unconformably overlies the Darwin Canyon Formation with an angular discordance of as much as 25°. This sequence, which we divide into five numbered units, is partly correlative with lithologically similar Triassic strata in the southern Inyo Mountains about 5 km northwest of the map area (Merriam, 1963). Lewis and others (1983) reported the presence of Early Triassic conodonts, ammonoids, and pelecypods in exposures near Darwin Canyon. Hall and MacKevett (1962) did not recognize these rocks as Triassic in age, and mapped them as part of the Owens Valley Formation. They interpreted the unconformable contact between these rocks and the underlying Permian rocks as an intraformational unconformity within the Permian sequence.

An incomplete section of Triassic rocks (unit 1 and part of unit 2) conformably or paraconformably overlies the Conglomerate Mesa Formation on the west side of Conglomerate Mesa. McAllister (1956) mapped these Triassic rocks as part of the Bird Spring(?) Formation, and Hall and MacKevett (1962) mapped them as part of the Owens Valley Formation.

JURASSIC AND CRETACEOUS(?) IGNEOUS ROCKS

GRANITOID ROCKS

Exposures of granitoid rocks in the map area represent the east margin of the Sierra Nevada batholith. Two major petrologic suites, calc-alkalic and alkalic, make up most of this part of the batholith (Miller, 1977, 1978; Dunne and others, 1978; Sylvester and others, 1978; Bateman, 1981; Dunne, 1986), and rocks of both suites crop out in the map area. The calc-alkalic suite is represented by quartz-rich rocks, mainly quartz monzonite and granite, that crop out on the west flank of the Darwin Hills and in Osborne Canyon and at Zinc Hill in the Argus Range. These rocks are chemically and petrologically similar to granitoid rocks exposed in the Sierra Nevada to the west. The alkalic suite is represented by rocks relatively poor in quartz, primarily quartz monzonite, monzonite, and monzodiorite, that crop out in the Darwin Hills, the Santa Rosa Hills, and near Panamint Springs in the Argus Range. These rocks are considered part of the alkalic Hunter Mountain batholith (Dunne, 1986). In addition to other petrologic and chemical distinctions, the alkalic granitoid rocks commonly contain between 5 and 25 percent less quartz for a given ratio of K-feldspar to plagioclase than do the calc-alkalic ones.

Isotopic ages that have been determined for granitoid rocks within the map area are 156 Ma (Late Jurassic) for a calc-alkalic rock in the western Darwin Hills (U-Pb; Chen and Moore, 1982), 174 Ma (Middle Jurassic) for an alkalic rock in the central Darwin Hills (U-Pb; Chen and Moore, 1982), and 185 Ma (Middle Jurassic) for an alkalic rock in the Argus Range (K-Ar; Hall and MacKevett, 1962) (time scale of Harland and others, 1982). Both the calc-alkalic and the alkalic granitoid rocks are cut by dikes (described below) that are thought to be part of the Late Jurassic Independence dike swarm. The only large body of granitoid rocks lacking these dikes is the calc-alkalic body at Zinc Hill, which could be Cretaceous in age.

DIKES

Present throughout the map area, but especially abundant in the Argus Range, are dikes of predominantly dioritic composition. Several workers have interpreted these undated dikes to be part of the Independence dike swarm of latest Jurassic age (148 Ma), which extends from the Sierra Nevada to the Mojave Desert (Moore and Hopson, 1961; Smith, 1962; Chen and Moore, 1979).

Most of the dikes in the map area strike between N. 10° W. and N. 80° W., with an average strike of N. 60° W., and nearly all of them dip within 10° of vertical. They range mostly between 0.5 and 6 m wide, and average about 1.5 m wide. The dikes intrude most of the pre-Cenozoic rock units and clearly postdate most of the north- to northwest-trending structural features. Some dikes within granitoid rocks west of the Darwin Hills, however, are cut by northwest-trending reverse-slip shear zones. Most of the dikes apparently occupy tension fractures, although a few, especially in the Argus Range, evidently intruded pre-existing faults.

Most of the dikes have mineralogic compositions and textures ranging from microdiorite to andesite, although a few are microgranite. Dikes of all compositions are moderately to thoroughly altered. The dikes commonly have phenocrysts of hornblende, plagioclase, or both in a plagioclase-rich groundmass. The major-element chemistry of one representative sample from Darwin Wash is typical of andesite (sample OW-13 of Chen and Moore, 1979).

STRUCTURAL GEOLOGY

PERMIAN STRUCTURES

The oldest structure exposed in the map area is a folded thrust fault (Fishhook thrust) that involves strata of the Perdido Formation, Rest Spring Shale, and Keeler Canyon Formation in the hills east of Conglomerate Mesa. This thrust fault, an overturned syncline in its lower plate, and an upright, south-plunging anticline-syncline couplet that folds the thrust fault all are interpreted to have formed during Early Permian (middle Wolfcampian) time (Stevens and Stone, 1988). The primary evidence for this interpretation is that the anticline-syncline couplet which folds the Fishhook thrust disappears abruptly upsection above unit 2 of the sedimentary rocks of Santa Rosa Flat, implying that folding ceased shortly after this unit was deposited. The abutment unconformity between the Keeler Canyon Formation and the sedimentary rocks of Santa Rosa Flat is interpreted to have developed concurrently with the development of the anticline-syncline couplet, shortly after movement on the Fishhook thrust had ceased.

A related Early Permian thrust fault (Lee Flat thrust) is inferred to exist in the subsurface between the Santa Rosa Hills and the Conglomerate Mesa area, separating the lithologically distinct sequences of Mississippian to lowermost Permian strata exposed in these two areas (Stevens and Stone, 1988). The Fishhook thrust is inferred to be in the upper plate of the Lee Flat thrust. The upper plates of both thrusts are interpreted to have moved in an easterly direction with respect to the lower plates. Displacement on the Fishhook thrust probably was minor, whereas that on the Lee Flat thrust probably was at least several kilometers.

The angular unconformity between the Darwin Canyon Formation and the unnamed Lower Triassic strata in the Darwin Canyon area provides further evidence of Permian deformation. Regional studies (Stone, 1984; Stone and Stevens, 1984) suggest that this unconformity reflects the development of broad, north- to northeast-trending structural arches primarily during Leonardian time. The local absence of the Panamint Springs Member of the Darwin Canyon Formation beneath the unconformity demonstrates that at least 1,000 m of strata was eroded during or subsequent to deformation. In the Inyo Mountains northwest of the map area, a similar unconformity is clearly overlapped by the Conglomerate Mesa Formation, which in turn is conformably overlain by Lower Triassic rocks correlative with those exposed in the Darwin Canyon area. Thus, most of the uplift and erosion is considered to have occurred before late Guadalupian time.

MESOZOIC FOLDS AND THRUST FAULTS

The map area is part of a belt of intense, generally east-vergent contractile strain that lies along the east margin of the Sierra Nevada batholith and is in part cogenetic with emplacement of the batholith (Dunne, 1986). Deformation in this belt began at the close of a period of relative tectonic quiescence that spanned part or all of the Triassic (Oborne and Dunne, 1982). Major thrust faults and folds developed periodically throughout much of the remainder of the Mesozoic and possibly the early Cenozoic.

A complex group of Mesozoic thrust faults dominates the structure of the Talc City Hills and Darwin Hills. Here, observed and inferred thrust faults separate four major structural plates, each of which has its own distinctive Paleozoic stratigraphy (figs. 2, 3). From the structurally lowest to the structurally highest, we refer to these plates as plates 1, 2, 3, and 4.

Structural plate 4, the highest plate, is composed of Cambrian to Mississippian strata, including the siltstone member of the Perdido Formation. This plate is separated from subjacent plate 3 (or, in places, from plate 1) by the Talc City thrust, which was named by Hall and MacKevett (1962). Plate 3 is composed of Devonian to Pennsylvanian or Permian strata, including, as does plate 4, the siltstone member of the Perdido Formation. Plate 3 differs from plate 4, however, in having a completely overturned stratigraphic section. We interpret plate 3 as the detached inverted limb of a large recumbent fold overridden on the Talc City thrust by the generally upright plate 4. Gulliver (1976), Dunne and others

(1978), and Dunne (1986
of a group of roughly
Chance thrust system, an
thrust fault, which is
jacent plates.
Structural plate 2 is c
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the Rest Spring Shale, an
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that plate 2 underwent
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extends for a distance
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Plate 1 encompasses
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Gulliver (1976) document
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folds.

MESOZ

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Santa Rosa Flat. The larg
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angle. Apparently related
to moderately west-dippi
to units 10, 11, and 12. Th
of 250 m and less. To the
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LATE MES

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These include: (1) the Da
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One of the most pro
trending, left-lateral Darw
which was first described
Hall and MacKevett (196
flank of the Argus Range
and from there probably
prominent subvertical fau
extension of the Darwin f
fault at the west base of t
faults in the Darwin Hills
apparent left-lateral separ
fault.
In the Darwin Hills, t
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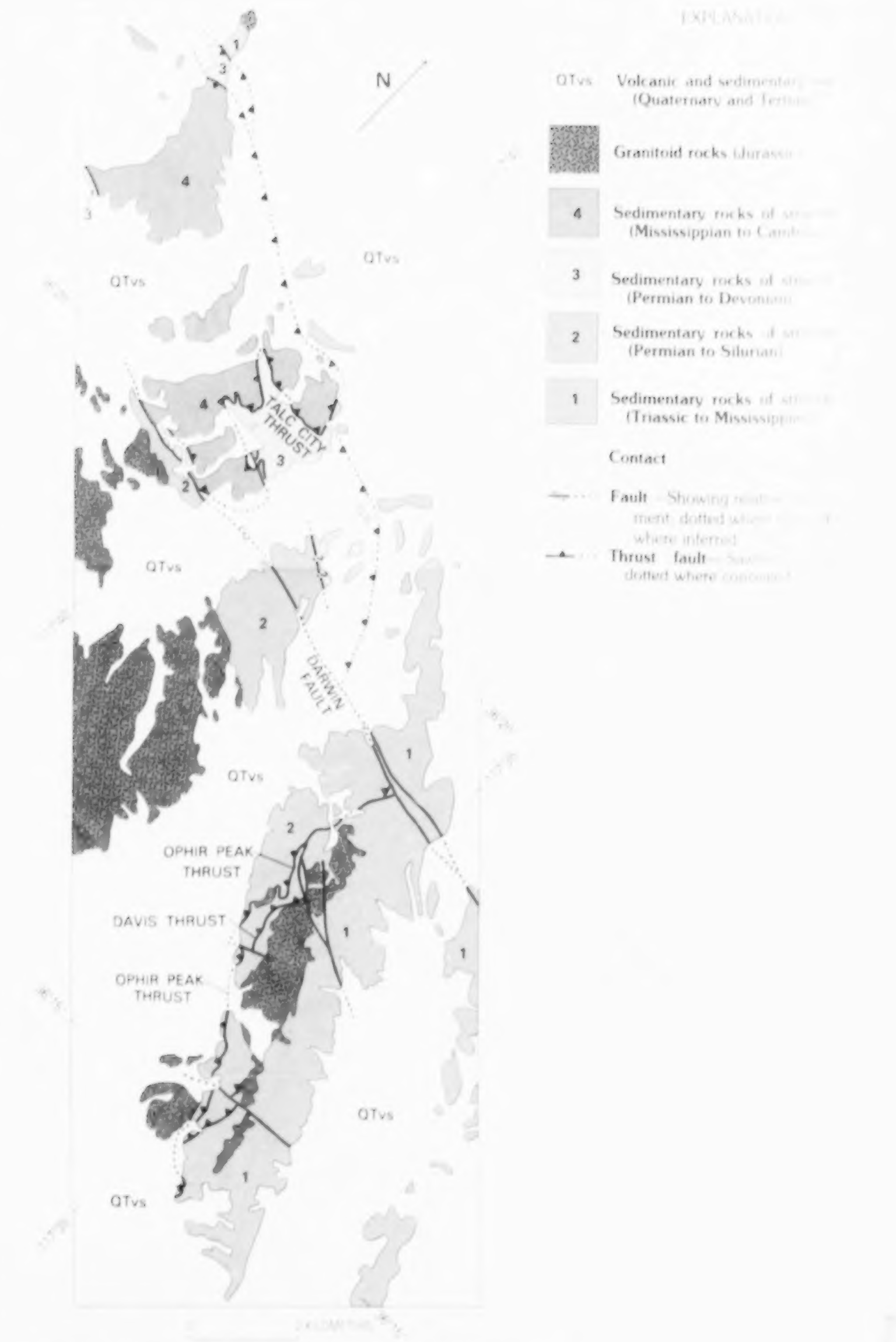
strata on the south. Meta
contact aureole of the 17
fault evidently postdates t
ped by basalt of probable
eral displacement, althou
zontal slickensides in the
minor movement after th
Canyon cuts Jurassic gra
alluvium.
We estimate left-later
1.6 km, based on the app
Spring and Panamint Spr
in Darwin Canyon. Hall a
displacement to be about
Talc City Hills. Paleozoic
fault and its probable w
drag, confirming the left-la
Another prominent
south end of the Santa Ro
displaced Tertiary basalt
the fault trace show prom
had substantial left-latera
Based on the degree
them, we interpret the Da
Santa Rosa Hills to bound
As first noted by Kelley, n
about 10 km along the
a northwestward pro
projection of the structural
system on the west side
The steeply dipping fa
interpret to offset the
minor normal displacemen
placement. Like the Darw
probable late Miocene

The pluton underlying
aureole of metamorphos
rocks are completely
metamorphosed
bounding the pluton
with, and possibly
Darwin fault into
the intrusive complex
nate against the west

Figure 4. ...
tween ...
Swansea ...
thrust in the ...
by a left-later...
Darwin fault ...
Kelley and ...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QTvs
1
2
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OPHIR PEAK THRUST
EXPLANATION
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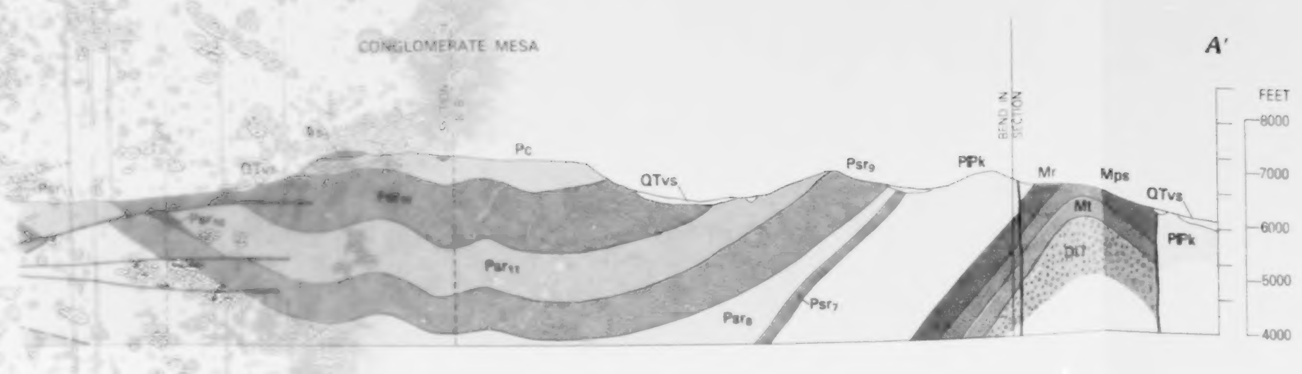
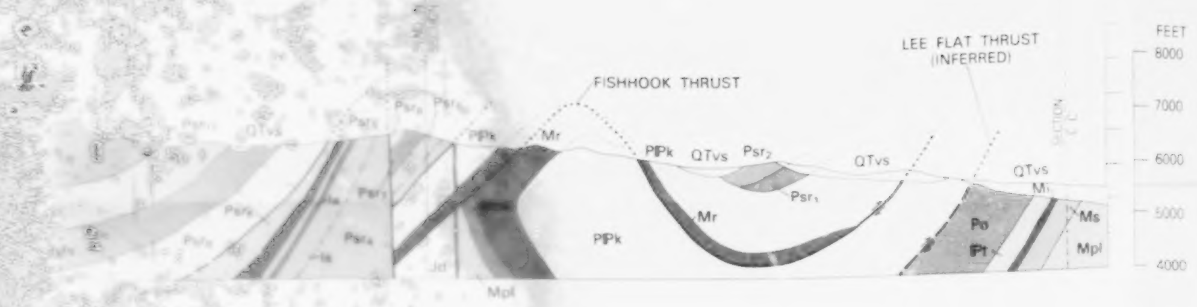
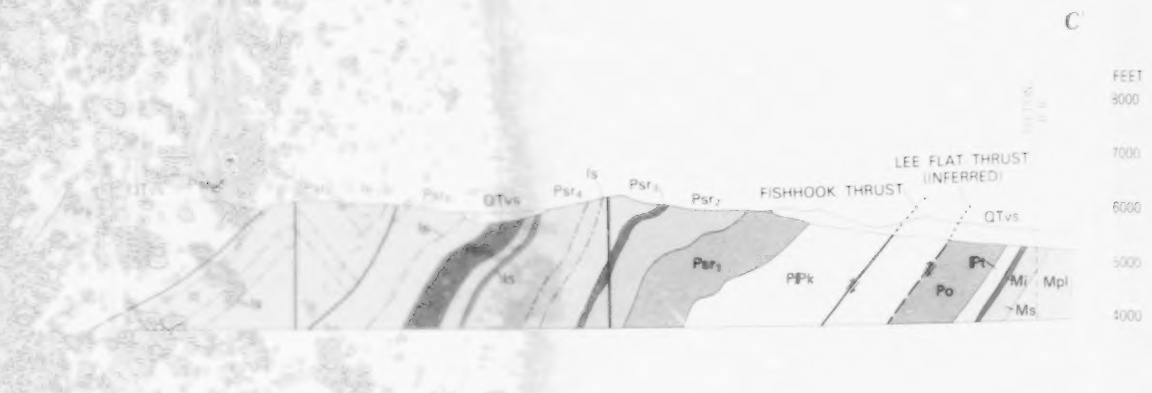
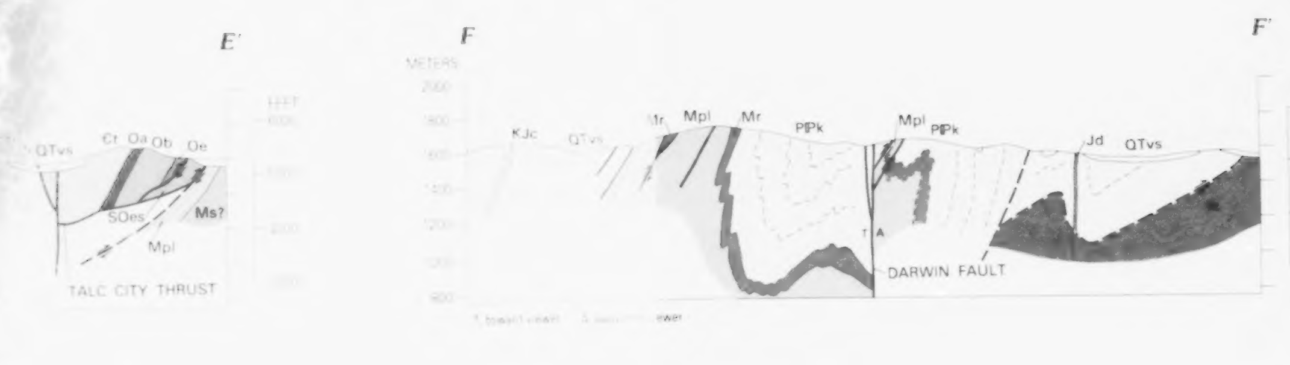
Granitoid rocks (Jurassic ...
4 Sedimentary rocks of ... (Mississippian to Cambrian ...
3 Sedimentary rocks of ... (Permian to Devonian ...
2 Sedimentary rocks of ... (Permian to Silurian ...
1 Sedimentary rocks of ... (Triassic to Mississippian ...
Contact
Fault—Showing relative ... dotted where concealed
Thrust fault—... dotted where concealed

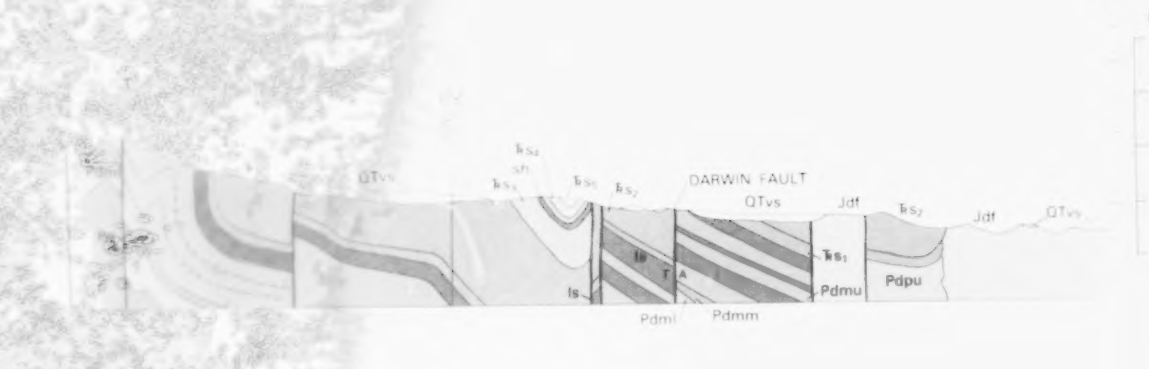
Figure 2. Simplified tectonic map of Darwin Hills and Talc City Hills showing faults bounding four major structural plates

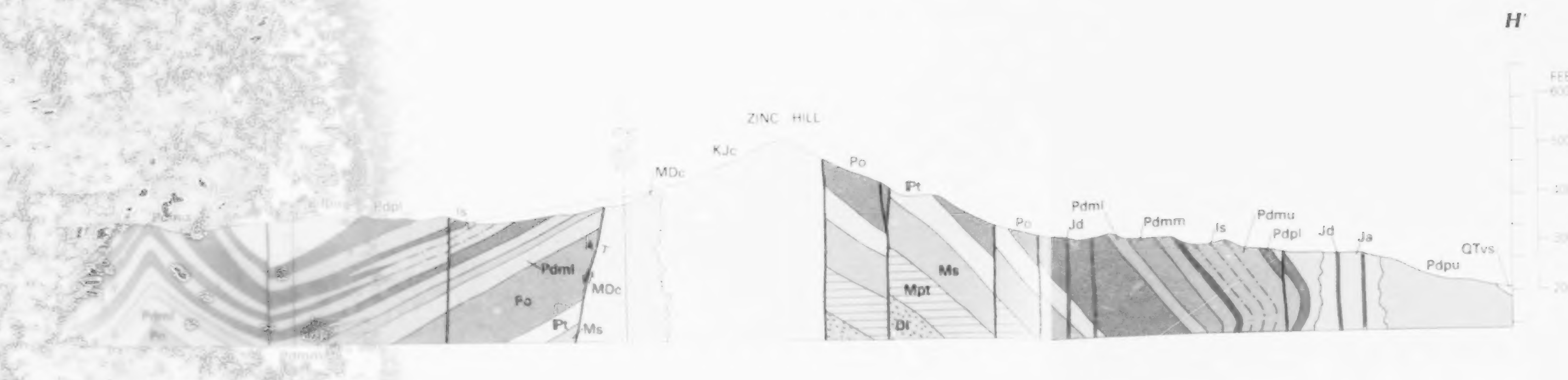


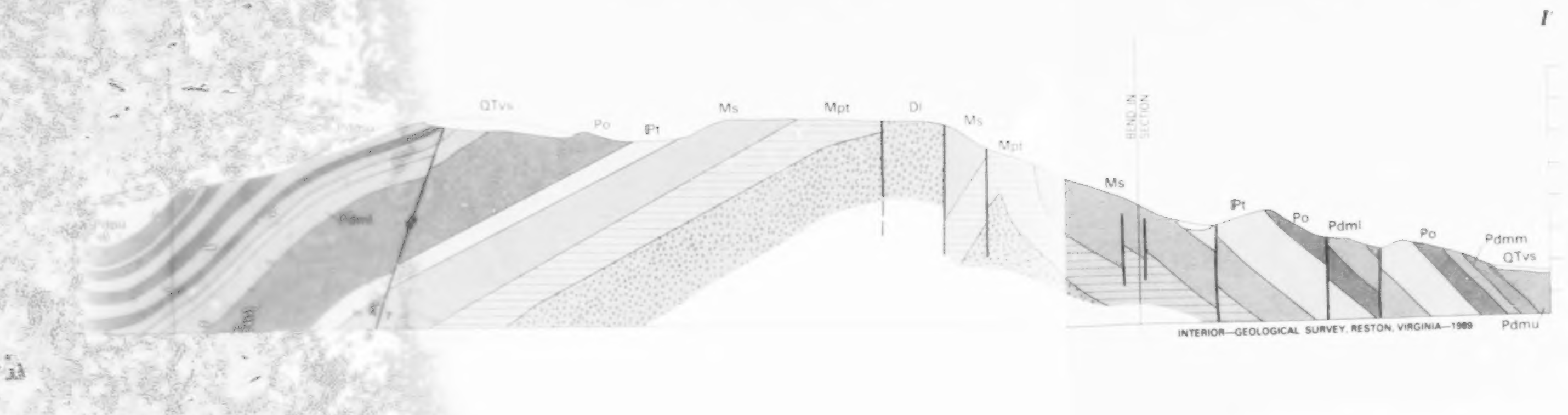












INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1989

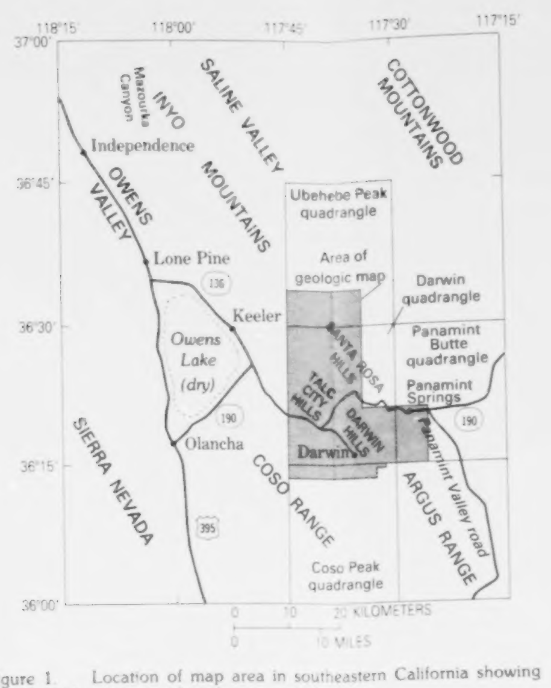


Figure 1. Location of map area in southeastern California showing names of 15-minute quadrangles covering the area.

INTRODUCTION

This map depicts the geology of Paleozoic and Mesozoic rocks exposed in the southeasternmost Inyo Mountains (Conglomerate Mesa area), the Santa Rosa Hills, the Talc City Hills, the Darwin Hills, the Darwin Canyon area, and the north end of the Argus Range, Inyo County, Calif. (fig. 1). The map area includes the majority of the Darwin 15-minute quadrangle, the southwest corners of the Ubehebe Peak and Panamint Butte quadrangles, and the northernmost part of the Coso Peak quadrangle. The map area contains an unusually complex Cambrian to Triassic stratigraphic record that has numerous implications for the paleogeography of the southwest end of the Cordilleran miogeosynclinal belt, and an excellent record of Mesozoic structural deformation along the east margin of the Sierra Nevada batholith.

Except for the small part that lies within the Coso Peak quadrangle, the map area is covered by existing U.S. Geological Survey geologic maps. McAllister (1956) mapped the Ubehebe Peak quadrangle; Hall and MacKevett (1962) mapped the Darwin quadrangle; and Hall (1971) mapped the Panamint Butte quadrangle. In addition, Elayer (1974), Moffitt (1978), Werner (1979), and Prevost (1984) mapped parts of the area as the basis for master's theses. The map we present here shows more stratigraphic and structural detail than earlier maps, corrects some previous misinterpretations, and incorporates recent changes in stratigraphic nomenclature. Except for the outlines of isolated granitoid rock outcrops south of the Santa Rosa Hills, which are from Hall and MacKevett (1962), we compiled this map entirely from our own work, including that of Gulliver (1976) and Stone (1984).

GENERAL GEOLOGIC FRAMEWORK

Most of the map area is underlain by sedimentary rocks of Late Cambrian to Early Triassic age. These rocks, which represent the southwesternmost part of the Cordilleran miogeosynclinal belt, consist of limestone, dolomite, shale, quartzose sandstone and siltstone, and minor conglomerate. They are intruded by Jurassic and Cretaceous(?) granitoid rocks that lie along the east margin of the Sierra Nevada batholith. Near intrusive bodies, the sedimentary rocks are strongly metamorphosed and mineralized. The sedimentary rocks are deformed by several generations of faults and folds that developed over much of Mesozoic and perhaps early Cenozoic time. The structurally complex Paleozoic and Mesozoic rocks are unconformably overlain by an extensive cover of flat-lying to gently dipping Tertiary volcanic rocks and by Quaternary alluvium and lake deposits. The Tertiary and older rocks are cut by basin-and-range normal faults of mostly undetermined displacement.

PALEOZOIC AND TRIASSIC STRATIGRAPHY

CAMBRIAN TO DEVONIAN ROCKS

The main exposures of Devonian and older rocks in the map area are in the Talc City Hills, which are underlain largely by rocks we assign to the Upper Cambrian Tamarack Canyon Dolomite, the Lower Ordovician Al Rose Formation, the Middle Ordovician Badger Flat Limestone and Eureka Quartzite, the Upper Ordovician and Lower Silurian Ely Springs Dolomite, the Lower Silurian to Lower Devonian Hidden Valley Dolomite, and the Middle and Upper Devonian Lost Burro Formation. The Hidden Valley Dolomite also is exposed in the northwestern Darwin Hills, and the Lost Burro Formation is exposed in the Argus Range, northwestern Darwin Hills, and Santa Rosa Hills. The Devonian and older rocks within the area represent deposition in various shallow-marine environments of the Cordilleran miogeocline (Stevens, 1986).

For the most part, the formation names we use for the Devonian and older rocks are the same as those used by Hall and MacKevett (1962), Hall (1971), and other previous workers. The only difference is that we reassign rocks mapped as the Pogonip Group by Hall and MacKevett (1962) to the Tamarack Canyon Dolomite, the Al Rose Formation, and the Badger Flat Limestone. These three formations have been traced discontinuously into the Talc City Hills from their type sections at Mazourka Canyon in the Inyo Mountains (fig. 1), but with the following changes in lithology (Stevens, 1986): (1) the Tamarack Canyon Dolomite in the Talc City Hills includes one or two thin intervals of siliceous mudstone not present at Mazourka Canyon, and contains lighter-colored zones and less chert than at Mazourka Canyon; (2) thin limestone beds in the predominantly siliceous Al Rose Formation at Mazourka Canyon are replaced by dolomite in the Talc City Hills; and (3) the Badger Flat Limestone is composed primarily of limestone at Mazourka Canyon and dolomite in the Talc City Hills.

Fossils have been useful in assigning the various dolomite units in the Talc City Hills to the appropriate formations (table 1). (1) We have found dome-shaped stromatolites only in the Tamarack Canyon Dolomite. (2) As noted by Hall and MacKevett (1962), the Badger Flat Limestone (their unit d of the Pogonip Group) commonly contains the large gastropods *Palliseria* and *Maclurites* and the sponge-like fossil *Receptaculites*. (3) The Ely Springs Dolomite locally contains a variety of tabulate corals (*Alveolites, Heliolites, Halysites, Favosites*), occasional rugose corals, and brachiopods (*Anastrophia, Rhyncotrema*). (4) The Hidden Valley Dolomite, although largely unfossiliferous, has yielded age-diagnostic conodonts at one locality (locality 18, table 1). (5) The Lost Burro Formation, which consists of both limestone and dolomite, is distinguished by the presence of massive stromatoporoids listed in table 1 as "*Stromatopora*" and the stemmed stromatoporoid *Amphipora*.

MISSISSIPPIAN ROCKS

Mississippian rocks are exposed at several localities in the Darwin quadrangle and vicinity, including the hills north and east of Conglomerate Mesa, the Santa Rosa Hills, the Talc City Hills, the Darwin Hills, and the Argus Range. Throughout the area, these rocks conformably overlie the Devonian Lost Burro Formation and are conformably or disconformably overlain by Pennsylvanian rocks.

Major lateral facies changes in the Mississippian rocks from southeast to northwest within the map area are reflected in the stratigraphic nomenclature. Mississippian rocks in the southeastern part of the area (Argus Range, southern Darwin Hills, and Santa Rosa Hills) predominantly consist of shelf limestone assigned to three widespread units, the Tin Mountain Limestone, the limestone member of the Perdido Formation, and the Santa Rosa Hills Limestone (Stevens and others, 1979; Dunne and others, 1981; Stevens, 1986). In the Santa Rosa Hills and southern Darwin Hills, the Santa Rosa Hills Limestone is overlain by a thin unit of Upper Mississippian quartzite and shale that we assign to the Indian Springs Formation of Webster and Lane (1967). A different Mississippian sequence is present in the northwestern part of the area (hills north of Conglomerate Mesa), where shelf limestone assigned to the Tin Mountain Limestone is overlain by Upper Mississippian siliciclastic rocks assigned to the siltstone member of the Perdido Formation and the Rest Spring Shale. These siliciclastic rocks represent a relatively deep-water (slope or basin) facies (Stevens and others, 1979; Stevens, 1986). The contact between the Tin Mountain Limestone and siltstone facies of the Perdido Formation in the northwestern sequence is considered to be a disconformity spanning the time during which the limestone member of the Perdido Formation was deposited to the southeast; the siltstone member of the Perdido Formation and the Rest Spring Shale are considered to be approximately coeval with the Santa Rosa Hills Limestone and Indian Springs Formation, respectively (Stevens and others, 1979; Dunne and others, 1981; Stevens, 1986). A variant of the northwestern Mississippian sequence is represented in the hills east of Conglomerate Mesa and in parts of the Talc City Hills, where Upper Mississippian limestone assigned to the limestone member of the Perdido Formation is present between the Tin Mountain Limestone and the siltstone member of the Perdido Formation.

In the Talc City Hills and Darwin Hills, Mesozoic thrust faults juxtapose the northwestern and southeastern Mississippian sequences described above with a third, lithologically transitional sequence that consists of the Tin Mountain Limestone, the limestone member of the Perdido Formation, and a thin shale unit assigned to the Rest Spring Shale. The upper part of the limestone member of the Perdido Formation in this transitional sequence is inferred to be coeval with the Santa Rosa Hills Limestone and the siltstone member of the Perdido Formation.

PENNSYLVANIAN AND PERMIAN ROCKS

Pennsylvanian and Permian rocks underlie most of the Conglomerate Mesa area, parts of the Santa Rosa Hills and the Talc City Hills, and most of the Darwin Hills, Darwin Canyon area, and Argus Range. Recent studies have shown that the Pennsylvanian and Permian rocks, like the underlying Mississippian rocks, undergo major lateral facies changes from southeast to northwest within the map area (Stone, 1984; Stone and Stevens, 1984, 1987; Stone and others, 1987). Although previous workers were aware of some of these facies changes, they did not attempt to map the various lithofacies as separate rock units. Hall and MacKevett (1962) and Hall (1971) mapped Pennsylvanian and Permian rocks throughout the area as the Keeler Canyon and Owens Valley Formations, both of which were defined in the Inyo Mountains northwest of the Darwin quadrangle; earlier, McAllister (1956) had mapped the Pennsylvanian and Permian rocks in the Conglomerate Mesa area as part of the Bird Spring(?) Formation. In order to emphasize the lateral facies changes, we distinguish the different facies as separate map units. Stone (1984), Stone and Stevens (1984, 1987), and Stone and others (1987) have discussed the facies changes and the associated variations in stratigraphic nomenclature in detail; we summarize the most important of them here.

We apply the name Keeler Canyon Formation to rocks of Pennsylvanian and earliest Permian age exposed in the northwestern part of the area, specifically in the hills north and east of Conglomerate Mesa, the Talc City Hills, and the west flank of the Darwin Hills. This formation, which overlies the Rest Spring Shale, constitutes a basinal facies consisting mainly of limestone turbidites (Stone, 1984; Stone and Stevens, 1984). A thin basal unit, not mapped separately, consists of gray micritic limestone that contains abundant nodular and lenticular chert. Previous workers have informally referred to this basal unit as the "golfball" horizon. We consider this basal unit equivalent to the Tihvipah Limestone, which was originally defined in the Cottonwood Mountains (northern Panamint Range) by McAllister (1952).

To the southeast, in the Santa Rosa Hills, southern Darwin Hills, and Argus Range, the Pennsylvanian is represented by a thin unit of cherty micritic limestone similar in lithology and age to the basal unit of the Keeler Canyon Formation. We map this unit as the Tihvipah Limestone. This formation, which probably represents an outer-shelf or slope facies, overlies the Indian Springs Formation or the Santa Rosa Hills Limestone and is overlain by Lower Permian rocks that form the basal part of the Owens Valley Group. At most localities, a disconformity representing the Upper Pennsylvanian and part of the Lower Permian separates the Tihvipah Limestone from the Owens Valley Group (Stone, 1984; Stone and Stevens, 1987), and no rocks corresponding either lithologically or temporally to the upper part of the Keeler Canyon Formation (that is, the part of that formation above the basal cherty limestone unit) are present. In the southern Darwin Hills, however, an unnamed thin, channelized sequence of limestone conglomerate, siltstone, and silicified limestone younger than the Tihvipah Limestone and older than the Owens Valley Group may be partly correlative with the upper part of the Keeler Canyon Formation.

The Permian Owens Valley Group, raised from formational rank by Stone and Stevens (1987), is extensively exposed within the map area. Throughout most of the area, the group consists of the Osborne Canyon Formation and the overlying Darwin Canyon Formation, both of which are Early Permian in age (Stone and others, 1987; Magginetti and others, 1988). These two formations are best exposed in Darwin Canyon and the Argus Range where their type sections are located, but also are widespread in the Darwin Hills where they are partially metamorphosed, and the Osborne Canyon Formation is recognized in the Santa Rosa Hills. The Osborne Canyon and Darwin Canyon Formations are composed mainly of siliceous and calcareous turbidites and debris-flow deposits representing slope and basinal environments of deposition. Limestone turbidites and debris-flow deposits in both formations contain fragments of colonial corals including *Stylastraea* (table 1), the presence of which is a reliable aid in distinguishing these formations from the somewhat similar Keeler Canyon Formation, which lacks fragments of this coral.

A somewhat different Permian sequence is present in the Conglomerate Mesa area, where the Owens Valley Group consists of the Upper Permian Conglomerate Mesa Formation (Stone and Stevens, 1987) and a thick sequence of Lower Permian strata which are informally referred to as the sedimentary rocks of Santa Rosa Flat (Stevens and Stone, 1988). The sedimentary rocks of Santa Rosa Flat are divided into twelve numbered units. Units 1–6, Wolfcampian in age, are basinal units consisting largely of calcareous and siliceous turbidites. These units are coeval with parts of the Osborne Canyon and Darwin Canyon Formations and contain similar rock types, but are distinguished from those formations on the basis of numerous lithologic details. Precise lithologic correlations, however, are considered to exist between unit 2 and the lower part of the Millers Spring Member of the Darwin Canyon Formation, and between unit 5 and the lower part of the Panamint Springs Member. Unit 7, latest Wolfcampian in age, is a lens of massive echinodermal limestone that apparently represents a shallow-water depositional setting. Unit 8, Leonardian in age, consists mainly of limestone turbidites but grades upsection and northward into limestone of relatively shallow-water origin. Some rocks in units 7 and 8 may be the same age as parts of the lithologically distinct Panamint Springs Member of the Darwin Canyon Formation. Units 9–12, Leonardian to early Guadalupian(?) in age, consist mainly of shallow-water rocks, and the overlying Conglomerate Mesa Formation of late Guadalupian age consists mainly of nonmarine rocks. Neither units 9–12 nor the Conglomerate Mesa Formation have lithologic or temporal counterparts in the southeastern part of the map area.

Units 1–6 of the sedimentary rocks of Santa Rosa Flat, which are more than 2,000 m thick in the area southeast of Conglomerate Mesa, thin rapidly northward and are absent in the area immediately north and northeast of Conglomerate Mesa. Unit 8, which is at least 1,000 m thick where it overlies unit 6 south and east of Conglomerate Mesa, thins to only about 50 m in the hills north of Conglomerate Mesa where it disconformably overlies the Keeler Canyon Formation. The pronounced lenticularity of these units resulted from northwestward depositional onlap against the Keeler Canyon Formation, which we interpret to have formed the surface of an elevated structural block at the margin of the basin in which the sedimentary rocks of Santa Rosa Flat accumulated (Stevens and Stone, 1988). Part of this onlap is exposed at a hill (elevation 6,719 ft) 3 km east of Conglomerate Mesa, where unit 2 wedges out depositionally along an abutment unconformity with the Keeler Canyon Formation. Our interpretation of this discordant contact differs from that of McAllister (1956), who mapped it as a fault within the Bird Spring(?) Formation.

Although the Owens Valley Group is almost entirely younger than the Keeler Canyon Formation, fossils indicate that the lowermost parts of the Osborne Canyon Formation in the southern Darwin Hills and northern Santa Rosa Hills are equivalent in age to the uppermost part of the Keeler Canyon Formation (Magginetti and others, 1988).

TRIASSIC ROCKS

An unnamed sequence of Lower Triassic marine strata between 800 and 900 m thick is discontinuously exposed from the east flank of the Darwin Hills to Darwin Canyon, where it unconformably overlies the Darwin Canyon Formation with an angular discordance of as much as 25°. This sequence, which we divide into five numbered units, is partly correlative with lithologically similar Triassic strata in the southern Inyo Mountains about 5 km northwest of the map area (Merriam, 1963). Lewis and others (1983) reported the presence of Early Triassic conodonts, ammonoids, and pelecypods in exposures near Darwin Canyon. Hall and MacKevett (1962) did not recognize these rocks as Triassic in age, and mapped them as part of the Owens Valley Formation. They interpreted the unconformable contact between these rocks and the underlying Permian rocks as an intraformational unconformity within the Permian sequence.

An incomplete section of Triassic rocks (unit 1 and part of unit 2) conformably or paraconformably overlies the Conglomerate Mesa Formation on the west side of Conglomerate Mesa. McAllister (1956) mapped these Triassic rocks as part of the Bird Spring(?) Formation, and Hall and MacKevett (1962) mapped them as part of the Owens Valley Formation.

JURASSIC AND CRETACEOUS(?) IGNEOUS ROCKS

GRANITOID ROCKS

Exposures of granitoid rocks in the map area represent the east margin of the Sierra Nevada batholith. Two major petrologic suites, calc-alkalic and alkalic, make up most of this part of the batholith (Miller, 1977, 1978; Dunne and others, 1978; Sylvester and others, 1978; Bateman, 1981; Dunne, 1986), and rocks of both suites crop out in the map area. The calc-alkalic suite is represented by quartz-rich rocks, mainly quartz monzonite and granite, that crop out on the west flank of the Darwin Hills and in Osborne Canyon and at Zinc Hill in the Argus Range. These rocks are chemically and petrologically similar to granitoid rocks exposed in the Sierra Nevada to the west. The alkalic suite is represented by rocks relatively poor in quartz, primarily quartz monzonite, monzonite, and monzodiorite, that crop out in the Darwin Hills, the Santa Rosa Hills, and near Panamint Springs in the Argus Range. These rocks are considered part of the alkalic Hunter Mountain batholith (Dunne, 1986). In addition to other petrologic and chemical distinctions, the alkalic granitoid rocks commonly contain between 5 and 25 percent less quartz for a given ratio of K-feldspar to plagioclase than do the calc-alkalic ones.

Isotopic ages that have been determined for granitoid rocks within the map area are 156 Ma (Late Jurassic) for a calc-alkalic rock in the western Darwin Hills (U-Pb; Chen and Moore, 1982), 174 Ma (Middle Jurassic) for an alkalic rock in the central Darwin Hills (U-Pb; Chen and Moore, 1982), and 185 Ma (Middle Jurassic) for an alkalic rock in the Argus Range (K-Ar; Hall and MacKevett, 1962) (time scale of Harland and others, 1982). Both the calc-alkalic and the alkalic granitoid rocks are cut by dikes (described below) that are thought to be part of the Late Jurassic Independence dike swarm. The only large body of granitoid rocks lacking these dikes is the calc-alkalic body at Zinc Hill, which could be Cretaceous in age.

DIKES

Present throughout the map area, but especially abundant in the Argus Range, are dikes of predominantly dioritic composition. Several workers have interpreted these undated dikes to be part of the Independence dike swarm of latest Jurassic age (148 Ma), which extends from the Sierra Nevada to the Mojave Desert (Moore and Hopson, 1961; Smith, 1962; Chen and Moore, 1979).

Most of the dikes in the map area strike between N. 10° W. and N. 80° W., with an average strike of N. 60° W., and nearly all of them dip within 10° of vertical. They range mostly between 0.5 and 6 m wide, and average about 1.5 m wide. The dikes intrude most of the pre-Cenozoic rock units and clearly postdate most of the north- to northwest-trending structural features. Some dikes within granitoid rocks west of the Darwin Hills, however, are cut by northwest-trending reverse-slip shear zones. Most of the dikes apparently occupy tension fractures, although a few, especially in the Argus Range, evidently intruded pre-existing faults.

Most of the dikes have mineralogic compositions and textures ranging from microdiorite to andesite, although a few are microgranite. Dikes of all compositions are moderately to thoroughly altered. The dikes commonly have phenocrysts of hornblende, plagioclase, or both in a plagioclase-rich groundmass. The major-element chemistry of one representative sample from Darwin Wash is typical of andesite (sample OW-13 of Chen and Moore, 1979).

STRUCTURAL GEOLOGY

PERMIAN STRUCTURES

The oldest structure exposed in the map area is a folded thrust fault (Fishhook thrust) that involves strata of the Perdido Formation, Rest Spring Shale, and Keeler Canyon Formation in the hills east of Conglomerate Mesa. This thrust fault, an overturned syncline in its lower plate, and an upright, south-plunging anticline-syncline couplet that folds the thrust fault all are interpreted to have formed during Early Permian (middle Wolfcampian) time (Stevens and Stone, 1988). The primary evidence for this interpretation is that the anticline-syncline couplet which folds the Fishhook thrust disappears abruptly upsection above unit 2 of the sedimentary rocks of Santa Rosa Flat, implying that folding ceased shortly after this unit was deposited. The abutment unconformity between the Keeler Canyon Formation and the sedimentary rocks of Santa Rosa Flat is interpreted to have developed concurrently with the development of the anticline-syncline couplet, shortly after movement on the Fishhook thrust had ceased.

A related Early Permian thrust fault (Lee Flat thrust) is inferred to exist in the subsurface between the Santa Rosa Hills and the Conglomerate Mesa area, separating the lithologically distinct sequences of Mississippian to lowermost Permian strata exposed in these two areas (Stevens and Stone, 1988). The Fishhook thrust is inferred to be in the upper plate of the Lee Flat thrust. The upper plates of both thrusts are interpreted to have moved in an easterly direction with respect to the lower plates. Displacement on the Fishhook thrust probably was minor, whereas that on the Lee Flat thrust probably was at least several kilometers.

The angular unconformity between the Darwin Canyon Formation and the unnamed Lower Triassic strata in the Darwin Canyon area provides further evidence of Permian deformation. Regional studies (Stone, 1984; Stone and Stevens, 1984) suggest that this unconformity reflects the development of broad, north- to northeast-trending structural arches primarily during Leonardian time. The local absence of the Panamint Springs Member of the Darwin Canyon Formation beneath the unconformity demonstrates that at least 1,000 m of strata was eroded during or subsequent to deformation. In the Inyo Mountains northwest of the map area, a similar unconformity is clearly overlapped by the Conglomerate Mesa Formation, which in turn is conformably overlain by Lower Triassic rocks correlative with those exposed in the Darwin Canyon area. Thus, most of the uplift and erosion is considered to have occurred before late Guadalupian time.

MESOZOIC FOLDS AND THRUST FAULTS

The map area is part of a belt of intense, generally east-vergent contractile strain that lies along the east margin of the Sierra Nevada batholith and is in part cogenetic with emplacement of the batholith (Dunne, 1986). Deformation in this belt began at the close of a period of relative tectonic quiescence that spanned part or all of the Triassic (Oborne and Dunne, 1982). Major thrust faults and folds developed periodically throughout much of the remainder of the Mesozoic and possibly the early Cenozoic.

A complex group of Mesozoic thrust faults dominates the structure of the Talc City Hills and Darwin Hills. Here, observed and inferred thrust faults separate four major structural plates, each of which has its own distinctive Paleozoic stratigraphy (figs. 2, 3). From the structurally lowest to the structurally highest, we refer to these plates as plates 1, 2, 3, and 4.

Structural plate 4, the highest plate, is composed of Cambrian to Mississippian strata, including the siltstone member of the Perdido Formation. This plate is separated from subjacent plate 3 (or, in places, from plate 1) by the Talc City thrust, which was named by Hall and MacKevett (1962). Plate 3 is composed of Devonian to Pennsylvanian or Permian strata, including, as does plate 4, the siltstone member of the Perdido Formation. Plate 3 differs from plate 4, however, in having a completely overturned stratigraphic section. We interpret plate 3 as the detached inverted limb of a large recumbent fold overridden on the Talc City thrust by the generally upright plate 4. Gulliver (1976), Dunne and others (1978), and Dunne (1986) have interpreted the Talc City thrust as part of a group of roughly aligned, geometrically similar thrust faults (Last Chance thrust system) active prior to 185 Ma. We infer another major thrust fault, which is nowhere exposed, to separate plate 3 from the subjacent plates.

Structural plate 2 is composed of Silurian to Pennsylvanian or Permian strata that include the limestone member of the Perdido Formation, the Rest Spring Shale, and the Keeler Canyon Formation. This plate is bounded below by a thrust fault here named the Ophir Peak thrust, which is exposed in the Darwin Hills. We interpret this thrust fault to have had two periods of movement, one before and one after intrusion of the 174-Ma alkalic pluton exposed in the Darwin Hills. The pre-plutonic movement, which may have been coeval with movement on the Talc City thrust, juxtaposed plate 2 against the underlying plate 1. The magnitude of the late Paleozoic lithofacies contrast between plates 1 and 2 suggests that plate 2 underwent substantial lateral displacement during this early phase of movement. The post-plutonic movement, during which the alkalic pluton of the Darwin Hills was partially truncated, was local and comparatively modest. The post-plutonic movement on the Ophir Peak thrust probably was related to that on the east Sierran thrust system (Dunne, 1986), a northwest-trending belt of thrust and reverse faults that extends for a distance of 340 km along the east margin of the Sierra Nevada batholith.

Structural plate 1, distinguished stratigraphically by the presence of the Santa Rosa Hills Limestone, Indian Springs Formation, Tihvipah Limestone and Owens Valley Group, is the relatively autochthonous block upon which the three structurally higher plates were emplaced. Plate 1 encompasses the eastern part of the Darwin Hills and the northernmost and easternmost parts of the Talc City Hills as well as the Conglomerate Mesa area, Santa Rosa Hills, Darwin Canyon area, and Argus Range.

In addition to the major plate-bounding thrust faults, numerous other thrust faults, reverse faults, and shear zones are present in the map area, particularly in the Talc City Hills and Darwin Hills. Most of these, including the Davis thrust of Hall and MacKevett (1962), appear to be of modest slip and probably are part of the east Sierran thrust system. Some of these faults truncate dikes of the Independence swarm.

North- to northwest-trending, east-vergent folds with well developed axial-plane cleavage are abundant in the map area. All of the four major plates and their bounding thrust faults are folded to some degree, with the intensity of folding and cleavage development decreasing irregularly eastward. The most spectacular folding is in the Talc City Hills, where Gulliver (1976) documented the intense folding of the Talc City thrust fault and its footwall and hanging-wall rocks. Rocks exposed in the Darwin Hills also are intensely folded. Folds and cleavage developed over an extended time. Some folds in the Darwin Hills, for example, appear to be truncated by the Ophir Peak thrust, which itself is deformed by younger folds.

MESOZOIC EXTENSIONAL FAULTS

A system of extensional faults exposed south and east of Conglomerate Mesa is here interpreted to be of Mesozoic age, as the faults apparently involve rocks as young as Triassic in age and one of the faults is crosscut by a dike presumed to be part of the Independence swarm. Faults of this system, which for the most part place younger over older rocks, have their greatest effect on the Lower Permian sedimentary rocks of Santa Rosa Flat. The largest of these faults separates units 6 and 8 of this Lower Permian sequence at the south end of the Conglomerate Mesa area; a structurally higher fault of similar geometry separates units 8 and 9 south of Conglomerate Mesa. Both of these faults cut bedding at a low angle. Apparently related to these low-angle faults are numerous steeply to moderately west-dipping extensional faults that are confined largely to units 10, 11, and 12. These minor faults have apparent displacements of 250 m and less. To the west, near the edge of the map area, the system of west-dipping faults appears to be cut off by a zone of steep to vertical faults whose downthrown side is to the east.

LATE MESOZOIC OR CENOZOIC FAULTS

The map area contains numerous faults that postdate Jurassic and Cretaceous(?) granitoid rocks and predate upper Miocene volcanic rocks. These include: (1) the Darwin fault and other east-trending faults, (2) a north-trending fault bounding the west side of the Argus Range, and (3) a system of faults surrounding Zinc Hill in the Argus Range.

One of the most prominent structures in the map area is the east-trending, left-lateral Darwin fault (previously called the Darwin tear fault), which was first described by Kelley (1937) and was again discussed by Hall and MacKevett (1962). This subvertical fault extends from the west flank of the Argus Range westward through the northern Darwin Hills, and from there probably continues west through the Talc City Hills. A prominent subvertical fault in Osborne Canyon probably is an eastward extension of the Darwin fault, displaced about 1.6 km southward on the fault at the west base of the Argus Range. Numerous other east-trending faults in the Darwin Hills and Darwin Canyon area, some of which have apparent left-lateral separation, may be tectonically related to the Darwin fault.

In the Darwin Hills, the Darwin fault juxtaposes unmetamorphosed Permian and Triassic strata on the north against metamorphosed coeval strata on the south. Metamorphosed strata south of the fault are in the contact aureole of the 174-Ma alkalic pluton of the Darwin Hills, so the fault evidently postdates the intrusion of this pluton. The fault is overlapped by basalt of probable late Miocene age that shows no major left-lateral displacement, although small offsets and the local presence of horizontal slickensides in the basalt demonstrate that the fault underwent minor movement after the basalt was extruded. The fault in Osborne Canyon cuts Jurassic granitoid rocks and is overlapped by Quaternary alluvium.

We estimate left-lateral displacement on the Darwin fault to be about 1.6 km, based on the apparent offset of the contact between the Millers Spring and Panamint Springs Members of the Darwin Canyon Formation in Darwin Canyon. Hall and MacKevett (1962) previously estimated the displacement to be about 970 m. Locally in the Darwin Hills and in the Talc City Hills, Paleozoic and Triassic strata on either side of the Darwin fault and its probable westward extension show pronounced sinistral drag, confirming the left-lateral nature of the fault.

Another prominent east-trending left-lateral fault is present near the south end of the Santa Rosa Hills. The trace of this fault is largely in little-displaced Tertiary basalt. However, Paleozoic rocks exposed adjacent to the fault trace show pronounced sinistral drag, suggesting that the fault had substantial left-lateral displacement before the basalt was extruded.

Based on the degree of sinistral bending of the rocks adjacent to them, we interpret the Darwin fault and the fault at the south end of the Santa Rosa Hills to bound a major east-trending zone of left-lateral shear. As first noted by Kelley and Stevens (1975), left-lateral displacement of about 10 km along this zone would explain the apparent offset between a northwestward projection of the Ophir Peak thrust and a southeastward projection of the structurally analogous basal thrust of the Swansea thrust system on the west side of the southern Inyo Mountains (fig. 4).

The steeply dipping fault at the west base of the Argus Range that we interpret to offset the Darwin fault into Osborne Canyon probably has minor normal displacement in addition to the apparent right-lateral displacement. Like the Darwin fault, this fault is overlapped by basalt of probable late Miocene age.

The pluton underlying Zinc Hill in the Argus Range and its contact aureole of metamorphosed Devonian and (or) Mississippian carbonate rocks are completely encircled by steep faults and separated from unmetamorphosed strata of Pennsylvanian and Permian age. The fault bounding the pluton and its contact aureole on the west is coincident with, and possibly superposed by, the fault that appears to displace the Darwin fault into Osborne Canyon. The faults north, east, and south of the intrusive complex make a semicircular trace that appears to terminate against the west bounding fault. The east bounding fault is overlapped by volcanic rocks of presumed late Miocene age. Although our mapping does not provide a definite interpretation of the faults around Zinc Hill, the pluton and its contact aureole appear to have intruded vertically upward into the Pennsylvanian and Permian section along these faults, almost in the manner of a diapir.

LATE CENOZOIC FAULTS

Only a few faults cut upper Miocene and Pliocene volcanic rocks exposed within the map area, and the only such faults we have mapped are those that have been observed to cut the older bedrock as well. None of these faults appear to have significant displacement, and none cut Quaternary alluvium. Details of the late Cenozoic structural history of the Darwin area are given by Schweig (1983).

FAULTS OF UNCERTAIN AGE

Structural cross section I–I' extending from the southern Darwin Hills eastward across Darwin Wash into the Argus Range reveals the presence of a major subsurface fault on the east side of the Darwin Hills. This fault is estimated to have about 1,000 m of vertical displacement with the east side down relative to the west side; we assume the fault to be a normal fault. The fault must die out rapidly to the north, because little or no displacement is required to achieve structural continuity in cross sections drawn from the northern Darwin Hills eastward into the Darwin Canyon area (Stone, 1984). The fault is probably of Tertiary age.

Low-angle surficial faults (slump blocks and landslide masses) of probable late Tertiary or Quaternary age are present on several of the high ridges in the map area, particularly the west side of the Darwin Hills, the west side of the northwest ridge of the Talc City Hills, and the east side of the Santa Rosa Hills. Some of the slump blocks in the Darwin Hills apparently moved along pre-existing thrust faults.

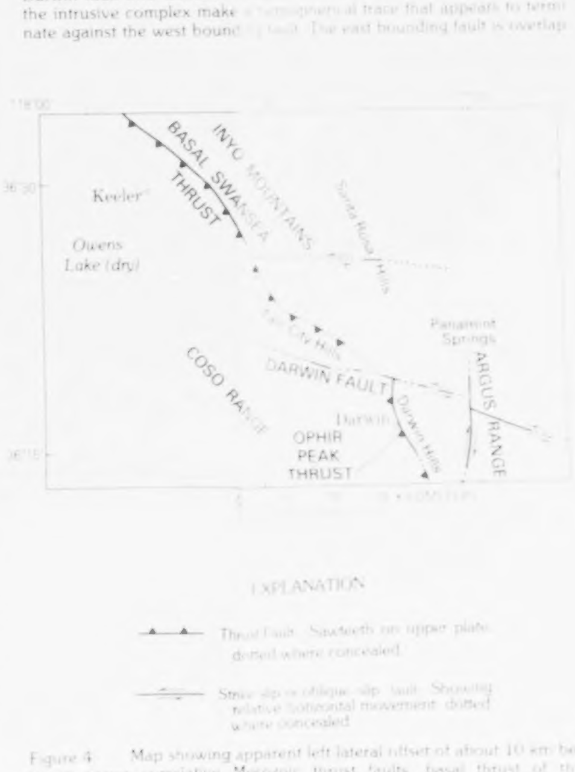


Figure 4. Map showing apparent left-lateral offset of about 10 km between the basal thrust of the Swansea thrust system in the Inyo Mountains and the Ophir Peak thrust in the Darwin Hills. Zone of apparent offset is bounded on north by a left-lateral fault in Santa Rosa Hills and on south by the Darwin fault. Location of Swansea thrust fault system from Kelley and Stevens (1975).

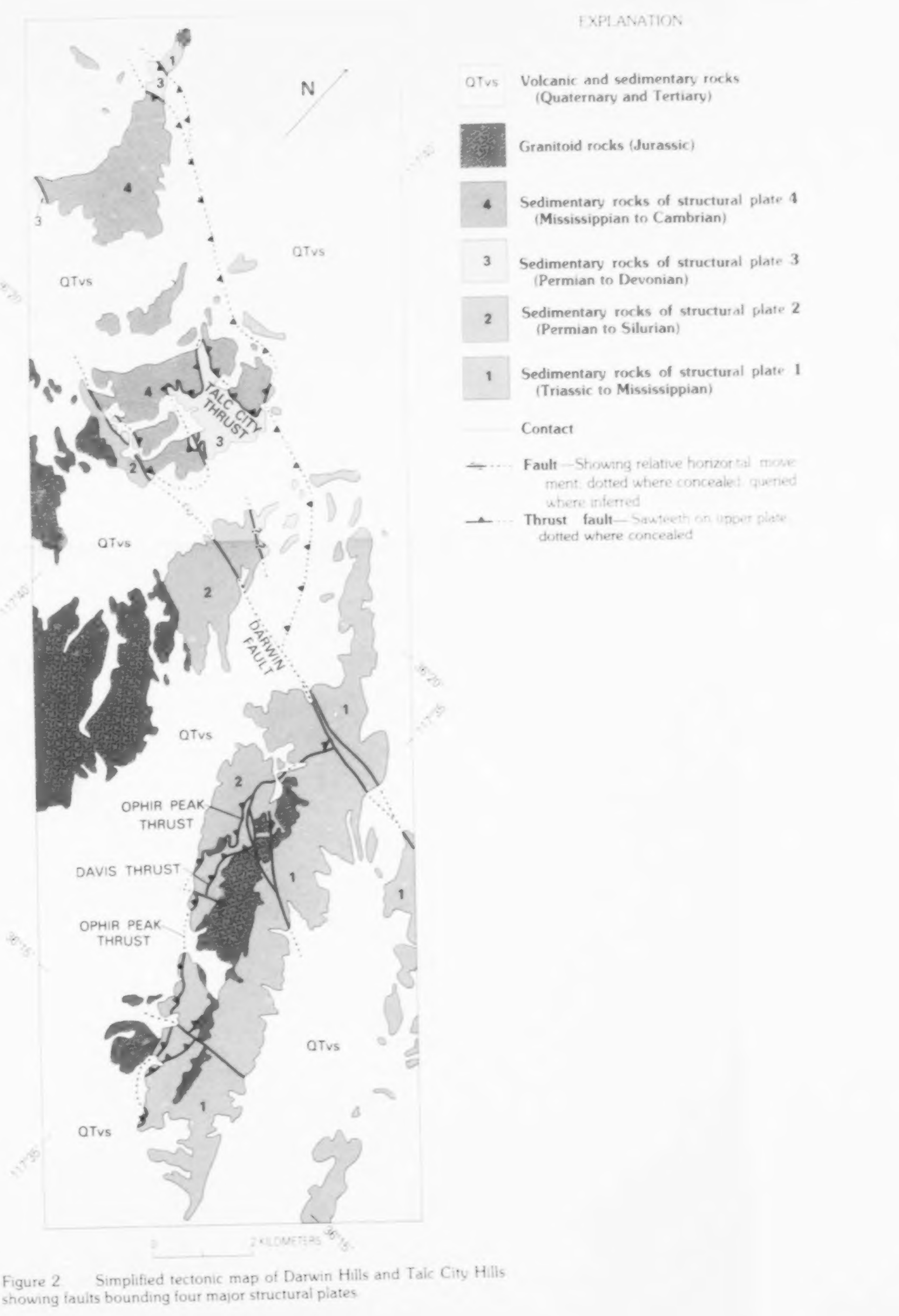

N
1
3
QTvs
TALC CITY THRUST
OPHIR PEAK THRUST
DAVIS THRUST
OPHIR PEAK THRUST
EXPLANATION
QTvs Volcanic and sedimentary rocks (Quaternary and Tertiary)
Granitoid rocks (Jurassic)
4 Sedimentary rocks of structural plate 4 (Mississippian to Cambrian)
3 Sedimentary rocks of structural plate 3 (Permian to Devonian)
2 Sedimentary rocks of structural plate 2 (Permian to Silurian)
1 Sedimentary rocks of structural plate 1 (Triassic to Mississippian)
Contact
Fault—Showing relative horizontal movement; dotted where concealed; queried where inferred
Thrust fault—Sawteeth on upper plate; dotted where concealed

Figure 2. Simplified tectonic map of Darwin Hills and Talc City Hills showing faults bounding four major structural plates.

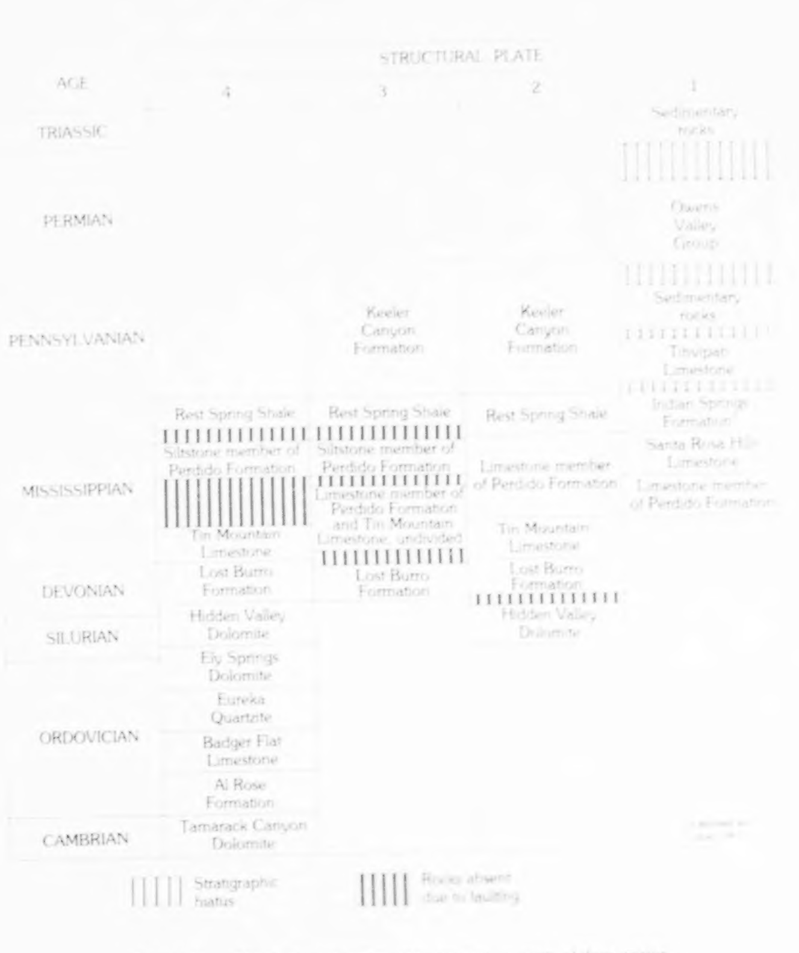


Figure 3. Chart showing map units present in each of four major structural plates in Darwin Hills and Talc City Hills.

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CROSS SECTIONS TO ACCOMPANY

IC AND MESOZOIC ROCKS IN PARTS OF THE DARWIN QUADRANGLES, INYO COUNTY, CALIFORNIA

By

rge C. Dunne, Calvin H. Stevens, and Rachel M. Gulliver

1989